Journal

of

THE ROYAL AERONAUTICAL SOCIETY

MARCH 1959

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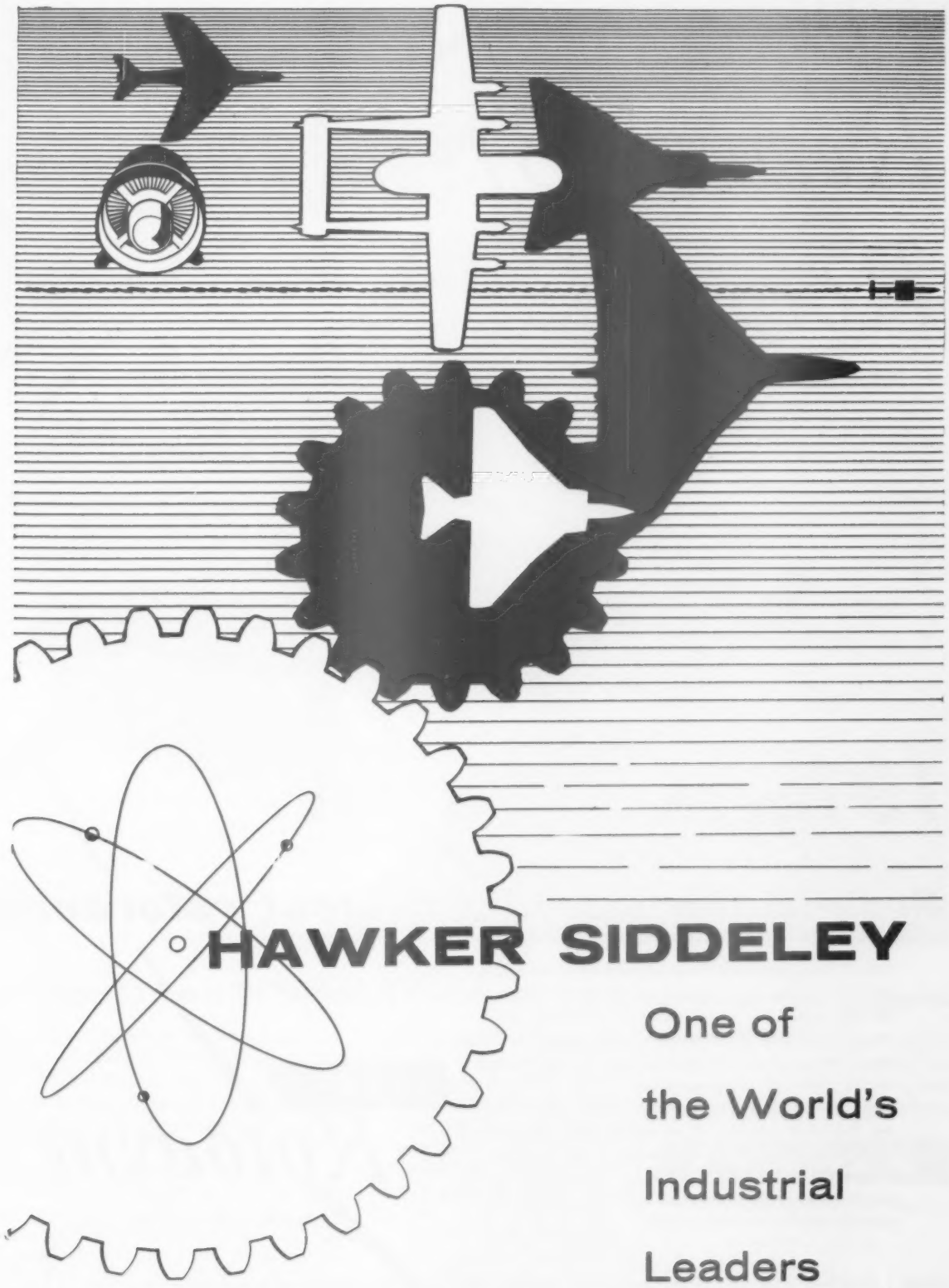
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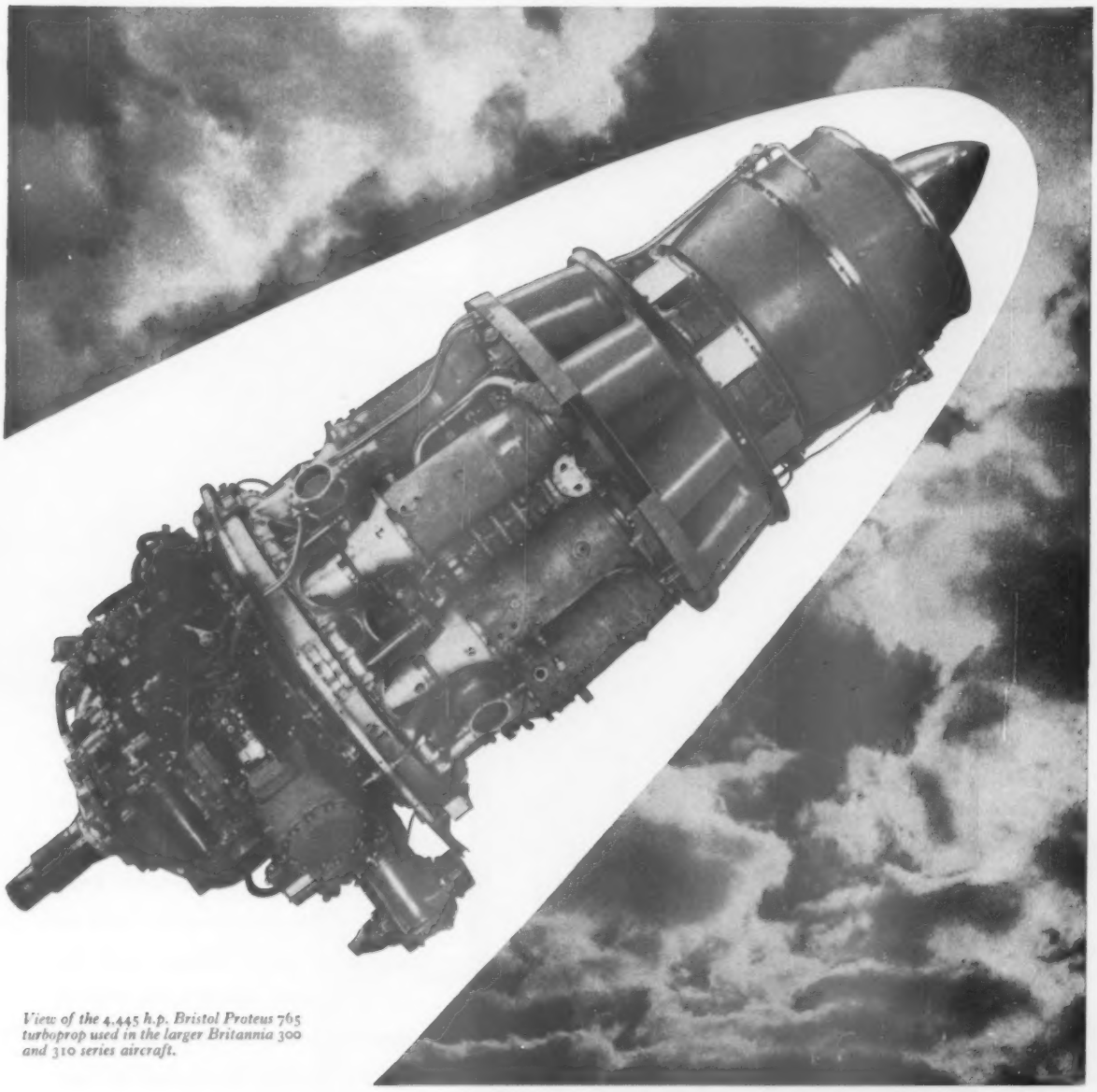

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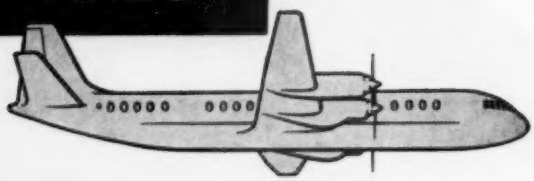

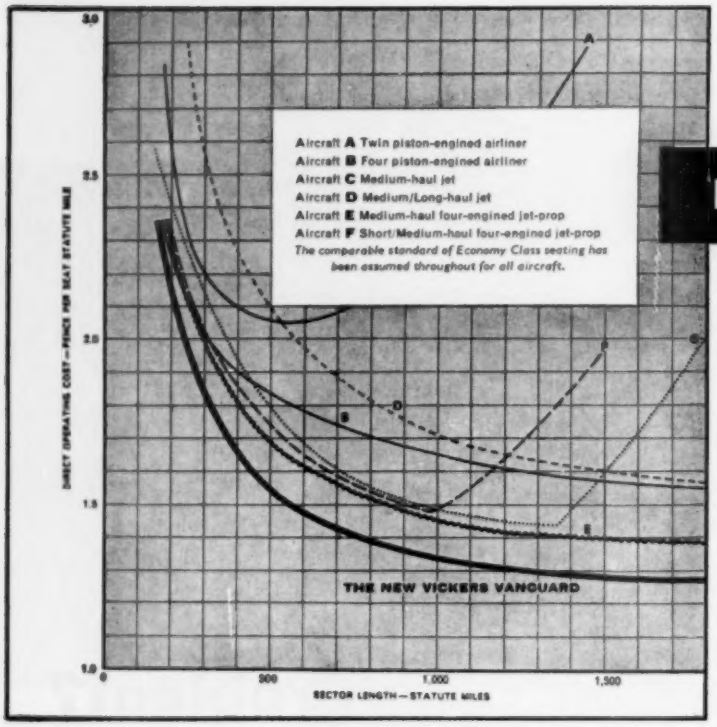

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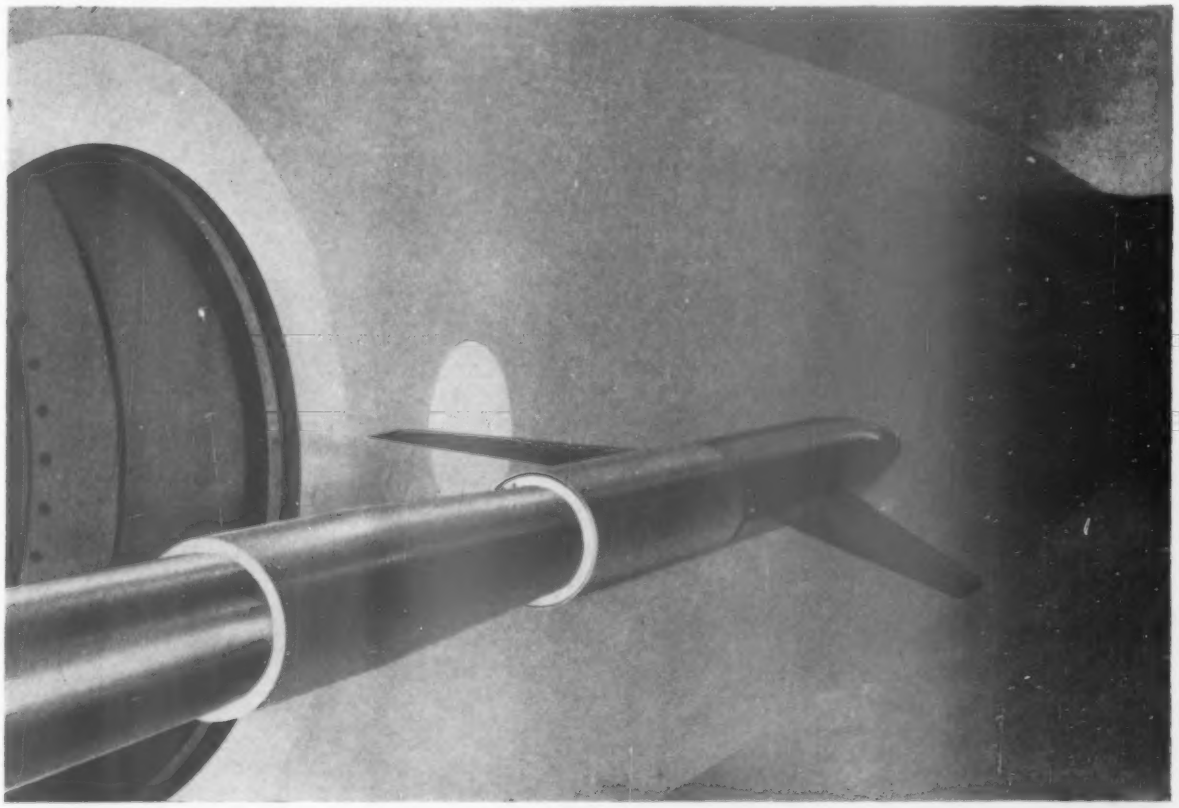

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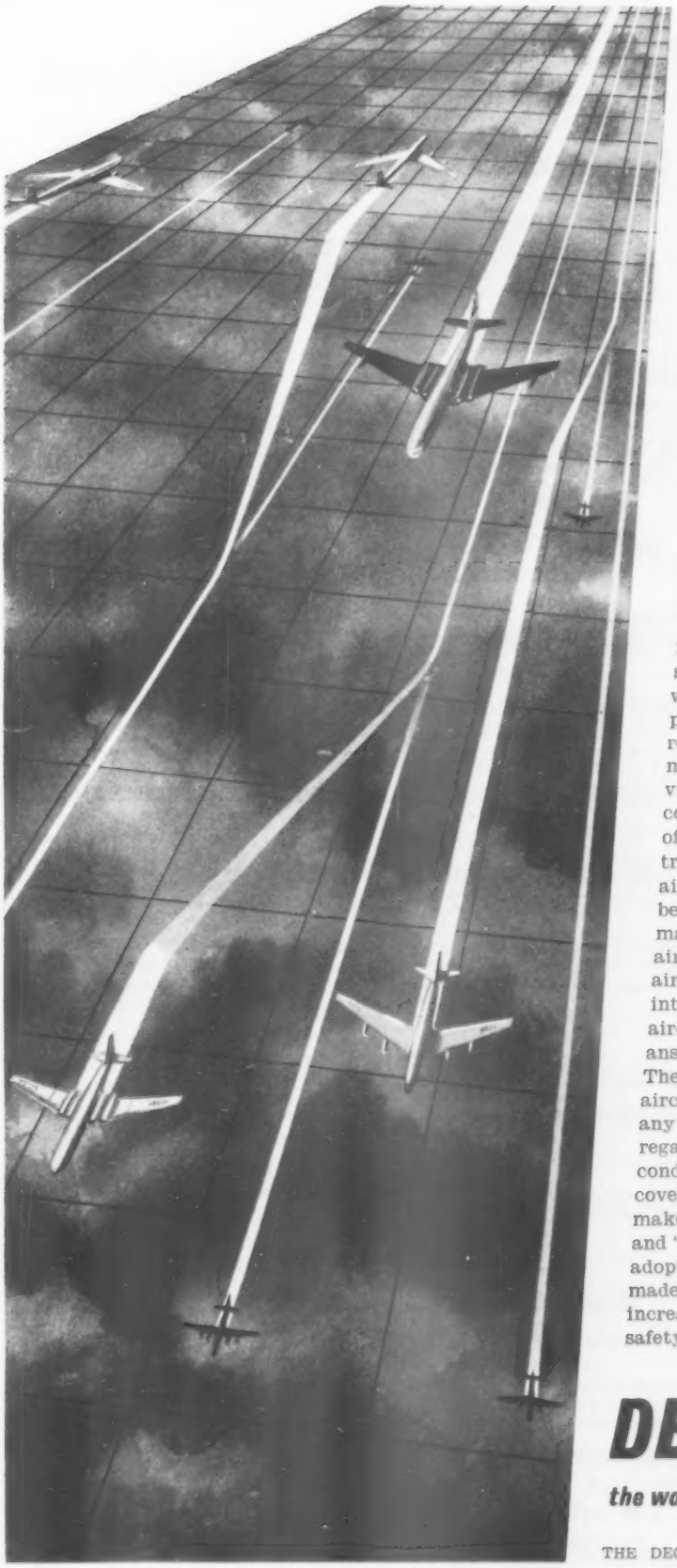

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SIR HARRY M. GARNER, K.B.E., C.B., M.A., F.R.Ae.S.

M. B. MORGAN, C.B., M.A., F.R.Ae.S.

F. M. OWNER, C.B.E., M.Sc.(Tech.), M.I.Mech.E., F.R.Ae.S.

SQUADRON LEADER R. C. G. T. ROGERS, D.C.Ae., A.F.R.Ae.S., R.A.F.

STEWART SCOTT HALL, C.B., M.Sc., D.I.C., F.C.G.I., F.I.A.S., F.R.Ae.S.

W. TYE, O.B.E., B.Sc., F.R.Ae.S.

T. A. WOLSTENHOLME, A.R.Ae.S.

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Solicitor: L. A. WINGFIELD, M.C., D.F.C., A.R.Ae.S.

Secretary: A. M. BALLANTYNE, T.D., B.Sc.(Eng.), Ph.D., Hon.F.C.A.I. F.I.A.S., F.R.Ae.S.

NOTICES

Seventh Anglo-American Aeronautical Conference

The Seventh Anglo-American Aeronautical Conference will be held from 4th-16th October 1959 and will open in New York. The Conference Headquarters, where all lectures will be held, will be at the Hotel Astor.

The following is the tentative programme which has been arranged:

Sunday 4th October:
Afternoon: Hotel Astor—Registration.
Evening: Informal Reception by I.A.S.

Monday 5th October:
Morning and Afternoon: Lectures.
Evening: Open.

Tuesday 6th October:
Morning and Afternoon: Lectures.
Evening: Open.

Wednesday 7th October:
Morning and Afternoon: Lectures.
Evening: Conference Dinner.

Thursday 8th and Friday 9th October:
Morning and Afternoon: Visits—Martin, Baltimore; F.A.A. Facility, Atlantic City *or* United Aircraft Corp., E. Hartford and Bridgeport; Republic and Grumman, Long Island *or* Wright Aero Corp. and Reaction Motors, Paterson and Denville, N.J.

Thursday 8th October:
Evening: Open.

Friday 9th October:
Evening: Dinner-Dance.

Saturday 10th October:
Morning, Afternoon and Evening: Open.

Sunday 11th October:
Morning: Open.
Afternoon: Delegates to be flown to Cleveland. (Heavy luggage and wives to Niagara Falls.)
Evening: Informal Reception and Buffet, Carter Hotel.

Monday 12th October:
Morning: Visit—N.A.S.A. Laboratories, Cleveland.
Afternoon: Visit—Ford Assembly Plant.
Evening: Reception and Buffet, Thompson Products Museum.

Tuesday 13th October:
Morning: Visit—Thompson Plant.
(Air Lift to Buffalo.)
Afternoon: Visit—Cornell Aero Laboratory, Buffalo; Bell Aircraft, Niagara.
Evening: Open. Delegates rejoin wives at Niagara Falls.

Wednesday 14th October:
Morning: Visit—Niagara Falls.
Afternoon: Bus to Toronto.
Evening: Open.

Thursday 15th October:
Morning and Afternoon: Visit—Toronto Area.
Evening: Dinner (arranged by C.A.I.).

Friday 16th October:
Morning and Afternoon: Visit—Toronto Area.

Further details and information about travel arrangements and registration will be announced shortly. It is hoped that as many members as possible will plan to attend the Conference accompanied by their wives.

A General Meeting of the Society—4th May

A General Meeting of voters of the Society will be held on Monday 4th May at 6 p.m. at 4 Hamilton Place, to consider proposed changes in the By-Laws of the Society.

Members have already been sent the Calling Notice for this meeting and the proposed changes in the By-Laws.

Annual General Meeting—7th May 1959

Notice is hereby given that the Annual General Meeting of the Royal Aeronautical Society, with which is incorporated the Institution of Aeronautical Engineers, will be held on Thursday 7th May 1959, at 5.30 p.m., in the Offices of the Society, 4 Hamilton Place, London W.1.

AGENDA

1. To read the Notice convening the Meeting.
2. To receive and deliberate upon the Report of the Council on the state of the Society and the Balance Sheet and Income and Expenditure Accounts of the Royal Aeronautical Society and Aeronautical Trusts Limited for the year ended 31st December 1958.
3. To receive the names of those elected to Council for the years 1959-1962.
4. To announce the names of Fellows elected by the Council in accordance with By-Law 4.
5. To elect the Auditors for the year 1959.
6. Any other business.

By Order of the Council,
A. M. BALLANTYNE,
Secretary.

Note: In accordance with the By-Laws any member whose subscription has not been paid before the first day of April is not entitled to vote.

Light refreshments will be served after the meeting.

Nomination of Candidates for Council

The following is an extract from the By-Laws:—

"The Twenty-one ordinary members (of the Council) shall be nominated and elected from among the members of the Society. At the date of their election at least ten shall be Fellows, and one at least shall be in each of the following classes: Associate Fellow, Associate and Graduate.

"Of the ordinary members of the Council that number necessary to create seven vacancies shall retire annually. The retiring members shall be those with the longest service since their last election but they shall be eligible for re-election.

"Nominations of candidates for election to the Council must be received by the Secretary not later than 10th April in each year and shall include statements in writing by the candidates that they are willing to serve. The nomination forms shall be signed by one proposer and two seconders, all of whom shall be Voters."

Nomination forms may be obtained from the Secretary.

Courtesy of "The Aeroplane"

Presidential Reception. The President, Sir Arnold Hall, with Lady Hall and Miss Caroline Hall.

All-Day Discussion on the Structural Effects of Kinetic Heating

Admission to the All-Day Discussion on the Structural Effects of Kinetic Heating on Tuesday 21st April 1959 *will be by special ticket only* for members *and* non-members. Applications for tickets should be made to the Secretary and until the *14th April* will be issued to members only. Thereafter any seats available will be issued to non-members in strict rotation.

The All-Day Discussion will begin at 9.45 a.m. at the Institution of Mechanical Engineers, Birdcage Walk, London, S.W.1. Four introductory papers will be given by C. L. Bore, A. J. Sobey, W. G. Heath and Dr. J. S. Przemieniecki. Further information will be published next month.

Honours Awarded to Members

Honorary Fellowship of the Institute of the Aeronautical Sciences has been conferred on Sir George Edwards, *Fellow*, Immediate Past-President of the Royal Aeronautical Society and Managing Director, Vickers-Armstrongs (Aircraft) Ltd.

Dr. A. M. Ballantyne, *Fellow*, Secretary of the Royal Aeronautical Society, has been elected a Fellow of the Institute of the Aeronautical Sciences.

Elliott Memorial Prize

The *Elliott Memorial Prize* for the first term in 1959 has been awarded to Warrant Officer Apprentice R. B. Thomson, and will be presented at the Halton Graduation Prizegiving on 25th March 1959.

The Late Mr. P. V. Cook

It was with great regret that the Council learned of the sudden death of Mr. P. V. Cook, at one time of the Aster Engineering Co., which built the production Green engines. Mr. Cook was mentioned in the February Journal notice of the award of Honorary Companionship to Mr. Gustavus Green. With his daughter, Mrs. Goodwin, also an engineer, Mr. Cook had been helping to restore two of the early Green engines.

Unfortunately the February Journal had gone to press before news of Mr. Cook's death reached the Society.

DIARY

LONDON

12th March

Twelfth Louis Blériot Lecture—The Griffon and the Prospect of Combining the Turbo-Ram-Jet Engine for Propulsion of Aeroplanes at High Speeds. Monsieur l'Ingénieur Général de l'Air Noël Daum. Institution of Mechanical Engineers, Birdcage Walk, S.W.1. 6 p.m. (Tea at 5.30 p.m.)

19th March

Lecture★—Long Range Missiles. E. C. Cornford. Institution of Civil Engineers, Great George Street, S.W.1. 6 p.m. (Tea at 5.30 p.m.)

9th April

Main Lecture—at Preston Branch—The Art of Developing Aero Engines. A. C. Lovesey. The Bull and Royal Hotel, Preston. 7.30 p.m.

21st April

All Day Discussion on the Structural Effects of Kinetic Heating. Institution of Mechanical Engineers, Birdcage Walk, S.W.1. 9.45 a.m. **Admission by special ticket only.** *See* special notice.

★ **Arranged by the Astronautics and Guided Flight Section.**

GRADUATES' AND STUDENTS' SECTION

25th March

Aircraft Escape Techniques. Wg. Cdr. J. Jewell. Library, 4 Hamilton Place. 7.30 p.m. (Coffee at 7 p.m.)

8th April

The American Aircraft Industry, by a member of the U.S. Air Attaché's Office. Library, 4 Hamilton Place. 7.30 p.m. (Coffee at 7 p.m.)

BRANCHES

16th March

Derby—The British Aircraft Industry. E. C. Bowyer. Rolls-Royce Welfare Hall, Nightingale Road. 6.15 p.m.

Henlow—Film Show. Building 62, R.A.F. Technical College. 7.30 p.m.

18th March

Christchurch—Materials for Supersonic Aircraft. G. Meikle. Kings Arms Hotel. 7.30 p.m.

Coventry—Servicing of Civil Aircraft. I. J. Gregory. Wine Lodge, Corporation Street. 7.30 p.m.

19th March

Isle of Wight—The Trials and Tribulations of Airline Operation. Captain J. N. M. Weir. Clubhouse, Saunders-Roe Sports and Social Club, Church Path, E. Cowes. 6 p.m.

24th March

Luton—Annual General Meeting. Napier Senior Staff Canteen, Luton Airport. 6.15 p.m.

25th March

Bristol—Annual General Meeting and Film Show. Filton House. 6 p.m.

Glasgow—New Supersonic Wind Tunnel (Blackburn and General Aircraft). A. C. Smith. Room 24, Royal College of Science and Technology. 7.15 p.m.

Preston—The Application of the Area Rule to Aircraft Design. W. T. Lord. Queen's Hotel, Lytham. 7.30 p.m.

Reading—Annual General Meeting and Film Show. Canteen, Western Manufacturing Ltd. 6.15 p.m.

Southampton—Annual General Meeting. Institute of Education, University of Southampton. 8 p.m.

Weybridge—(Joint meeting with the Institution of Mechanical Engineers.) Guidance and Control of Missiles. L. H. Bedford. Apprentice Training School, Vickers-Armstrongs (Aircraft) Ltd. 6.10 p.m.

26th March

Southend—Flying Boats. Labour Hall, Boston Avenue. 7.30 p.m.

27th March

Belfast—Modern Aircraft Inspection Techniques. J. C. Corlett. Lecture Hall LG8, David Keir Building, The Queen's University. 7 p.m.

1st April

Brough—Flying with the Trans-Antarctic Expedition. Sqn. Ldr. J. H. Lewis. Lecture Hall, Electricity Offices, Ferensway, Hull. 7.30 p.m.

Gloucester—Annual General Meeting and Film Show. The Wheatstone Hall, Brunswick Road. 7.30 p.m.

6th April

Derby—Design for Safety. D. P. Huddie. Rolls-Royce Welfare Hall, Nightingale Road. 6.15 p.m.

Glasgow—Graduates' and Students' Section — Annual General Meeting followed by three lecturettes. Room 24, Royal College of Science and Technology. 7.30 p.m.

7th April

Boscombe Down—The Development of the Rotodyne. Dr. G. S. Hislop. Lecture Hall, A. & A.E.E. 5.45 p.m.

London Airport—Power from Nuclear Energy. Dr. M. D. Wood. Lecture Hall, Fairey Aviation Co., Hayes. Preceded by the Annual General Meeting. 6.15 p.m.

Luton—Debate. Napier Senior Staff Canteen, Luton Airport. 6.15 p.m.

8th April

Chester—Soviet Civil Aviation. C. Jenkins. Lecture Theatre, Grosvenor Museum. 7.30 p.m.

Christchurch—Lecture by Mr. Allan. King's Arms Hotel. 7.30 p.m.

Reading—Experiences of an Airline Pilot. Capt. O. P. Jones. Canteen, Western Manufacturing Ltd. 6.15 p.m.

Weybridge—The Operation of London Airport. J. Jeffs. Apprentice Training School, Vickers-Armstrongs (Aircraft) Ltd. 6.10 p.m.

9th April

Isle of Wight—Lecture or Symposium by Branch Members. Clubhouse, Saunders-Roe Sports and Social Club, Church Path, E. Cowes. 6 p.m.

Preston—MAIN SOCIETY LECTURE—The Art of Developing Aero Engines. A. C. Lovesey. The Bull and Royal Hotel, Preston. 7.30 p.m.

Swindon—Film Show. The College, Victoria Road. 7 p.m.

13th April

Glasgow—Annual General Meeting. Room 24, Royal College of Science and Technology. 7.15 p.m.

Halton—Some Experiences of an Airline Pilot. Capt. O. P. Jones. Branch H.Q., R.A.F. Halton. 6.45 p.m.

14th April

Bristol—American Lecture. **POSTPONED** until September.

Brough—Annual General Meeting. Lecture Room, Flying Club, Brough. 5.10 p.m.

Coventry—Annual General Meeting. Wine Lodge, Corporation Street. 7.30 p.m.

22nd April

Hatfield—Discussion Evening. de Havilland Restaurant. 6.15 p.m.

23rd April

Preston—Annual General Meeting and Film Show. R.A.F. Association Hall, Preston. 7.30 p.m.

29th April

Christchurch—Annual General Meeting and Film Show. King's Arms Hotel. 7.30 p.m.

Weybridge—Annual General Meeting. Apprentice Training School, Vickers-Armstrongs (Aircraft) Ltd. 6.10 p.m.

BRITISH COUNCIL SCIENCE COURSES 1959-1960

The British Council is holding five advanced courses in the United Kingdom during 1959-60 for specialists from overseas in scientific subjects. They are on:—the application of electricity at civil airports; plant breeding; foot and mouth disease; ergonomics; digital computers. Each course lasts a fortnight and the fees, in most cases, will be £47 including accommodation.

Further details and application forms are obtainable from The British Council (Courses Dept.), 65 Davies Street, London W.1.

INTERNATIONAL AGRICULTURAL AVIATION CONFERENCE, 14th-19th SEPTEMBER 1959

The Society has joined with agricultural organisations and the Ministry of Transport and Civil Aviation in the organisation of a residential Conference on Agricultural Aviation at the College of Aeronautics, Cranfield, from 14th-19th September. Three days will be devoted to lectures, covering agricultural chemicals and fertilisers, aircraft and equipment, and economics and flying. On the fourth day a flying display and demonstration of equipment is being organised by the National Association of Agricultural Contractors.

Offers of papers or progress reports for discussion are invited, by 1st June, from European scientific or technical workers and operators, for submission to the Editorial Panel. Formal papers will be by invitation.

The comprehensive fee for the Conference, including accommodation and a copy of the Proceedings is £14. Details and registration forms may be obtained from:—Ministry of Agriculture, Fisheries and Food, Room 218, Great Westminster House, Horseferry Road, S.W.1, *or* Dr. W. J. Maan, Director of the European Agricultural Aviation Centre, le v.d. Boschstraat 4, The Hague.

TWO SYMPOSIA ON THE PROBLEM OF NOISE AND VIBRATION

The Acoustics Group of the Physical Society is sponsoring two symposia dealing with the problem of noise and vibration.

The first, "Recent Studies of Noise Problems," will be held on 24th March at 2.15 p.m. in the Physics Dept., Imperial College, S.W.7. Recent work on the measurement and effects of noise will be surveyed, with contributions on certain aspects of aircraft and automobile noise. The second, "New Techniques in the Analysis of Noise and Vibration," will be held on 7th April in the Physics Dept., Southampton University. It will include contributions from both practical and theoretical aspects on the use of correlation techniques, of digital computers for data processing and analysis, and on general applications of statistical communication theory.

Further details may be obtained from D. M. A. Mercer, Physics Dept., Southampton University.

THE JOHN DE HAVILLAND AWARD

With the agreement of Sir Geoffrey de Havilland the Trust Fund which was established in 1945 in memory of John de Havilland to provide financial help for boys wishing to take apprenticeship in the Aircraft Industry is now to be used for a new form of award which will again be administered by the Society of British Aircraft Constructors. The purpose of the new form of the Award is to develop the power of leadership and candidates are invited to make their own proposals for its use. The value will be £400 to cover a period not longer than one year. Candidates should be between 18 and 25 years of age, and should have the intention of making a career in the Aircraft Industry.

Further information and application forms (which must be returned by 15th May) may be obtained from the Society of British Aircraft Constructors Ltd., 29 King Street, St. James's, London S.W.1.

GARDEN PARTY PROGRAMMES

The Society's files of Garden Party Programmes are lacking certain numbers. The Librarian would be pleased to hear from any member who has any programmes for the years 1919—1939 and is willing to let the Society have them.

News of Members

R. W. Angell (*Associate Fellow*), formerly Resident Technical Officer, Saunders-Roe Ltd., now holds the same post at Martin-Baker Aircraft Co. Ltd.

E. R. Arbon (*Associate Fellow*), formerly Head of Engineering Laboratories, Bristol Aircraft Ltd., is now Research Manager (Engineering) with the United Kingdom Atomic Energy Authority at Windscale.

A. W. Ballinger (*Associate Fellow*), formerly in the Manchester District of the Aeronautical Inspection Directorate has been appointed Inspector-in-Charge, A.I.D. Cardiff District Office.

A. F. Boot (*Associate Fellow*), formerly Senior Engineer, Canadair Ltd., Montreal, is now a Development Engineer with de Havilland Propellers Ltd., Stevenage.

D. P. Bowker (*Student*), formerly a Pilot Officer with the Royal Air Force is now a Pilot with B.O.A.C.

The Viscount Caldecote (*Associate Fellow*), a director of the English Electric Group of Companies, has been appointed to the Board of Directors of D. Napier and Son Ltd.

J. C. Clayden (*Associate*), formerly a Sub-Contracts Engineer with the English Electric Co. Ltd., is now Works Co-ordination Engineer in the Administrative Department of de Havilland Propellers Ltd., Stevenage.

P. R. Crewe (*Associate Fellow*) is now Chief Engineer (Hydrodynamics) at Saunders-Roe Ltd., Isle of Wight.

Squadron Leader G. W. Ellis (*Associate Fellow*) has been posted from Wittering to take up duties in the Air Ministry (D.D.I. Tech.).

Squadron Leader M. V. Fox-Strangways (*Associate Fellow*) has recently been posted from Air Ministry (Directorate of Engineering, G.W.) to Headquarters Bomber Command as Guided Weapons Engineering I.

Wing Commander L. L. Harland (*Associate*), formerly at R.A.F. Bracknell is now Commanding No. I Guided Weapon Trials Squadron at R.A.F. Valley.

J. F. Harriman (*Associate Fellow*), formerly Head of Mechanical Development Section, Rolls-Royce Ltd., is now Deputy Head, Electro-Mechanical Division, Ericsson Telephones Ltd. (Correction from February Journal Notices.)

R. M. Howarth (*Associate Fellow*), formerly Chief Project Designer (Helicopters) of Bristol Aircraft Ltd., has been appointed Assistant Chief Engineer (Rocket Design) of Bristol Aerojet Ltd., Banwell, Somerset.

H. M. J. Kittelsen (*Associate Fellow*), formerly Senior Lecturer in Thermodynamics, Kingston Technical College is now Head of the Mechanical Engineering Dept., Southall Technical College.

Alan B. Lowe (*Associate Fellow*), formerly with the English Electric Co. Ltd. (Aircraft Division) at Warton, is now Senior Sales Engineer with the de Havilland Aircraft Co. Ltd., Hatfield.

J. M. McDermott (*Associate Fellow*), formerly with the Fairey Aviation Co. Ltd., is now a Stress Engineer with Avro Canada at Malton, Ontario.

W. C. F. Moxon (*Graduate*), formerly with Power Jets Ltd., is now a Contracts Engineer with General Electric Co. (Atomic Energy Division), Erith.

Ronald E. Nutley (*Associate*), formerly Senior Technical Assistant, Bristol Aeroplane Co. Ltd., is now with de Havilland Propellers Ltd. (London Office) as a Weight Engineer Section Leader.

C. L. Paice (*Associate Fellow*), formerly Senior Design Engineer, English Electric Co. Ltd., is now Manager of the Engineering Department at Pye Ltd., Royston.

G. I. Pauley (*Graduate*), formerly Technical Assistant, D. Napier and Son Ltd., is now Project Supervisor, Aircraft Research Association, Bedford.

A. J. Penn (*Fellow*), Chief Engineer of Napier's Aero Gas Turbine Division, has been appointed Technical Director of D. Napier and Son Ltd.

H. Sammons (*Fellow*), Managing Director of D. Napier and Son Ltd., has been appointed President of the new Napier Canadian subsidiary company, D. Napier and Son (Canada) Ltd.

R. J. Sanders (*Associate Fellow*), formerly Senior Stressman, Flight Refuelling Ltd., is now a Research Engineer in the Mechanical Engineering Department of the British Columbia Research Council in Vancouver.

J. C. K. Shipp (*Associate Fellow*) has been appointed a Director of the new Napier Canadian subsidiary company, D. Napier and Son (Canada) Ltd.

Air Commodore T. U. C. Shirley (*Fellow*), formerly Air Officer Commanding and Commandant of the R.A.F. Technical College, Henlow has been appointed Senior Technical Staff Officer at Headquarters Fighter Command with the acting rank of Air Vice-Marshal.

Flt. Lt. N. H. Smith (*Associate*) has left the U.S.A. and returned to Canada and is now with the R.C.A.F. Aircraft Armament Evaluation Detachment.

Wing Commander C. J. Turner (*Associate Fellow*), formerly in the Technical Engineering Department at the R.A.E., Farnborough, has taken up an appointment in the Directorate of Aircraft Engineering, Air Ministry.

D. Ulyett (*Graduate*), formerly Stress Engineer, Fairey Aviation Co. Ltd., is now a Stress Engineer with Avro Canada at Malton, Ontario.

A. E. White (*Associate*), formerly with Airwork Services Ltd., Gatwick Airport, is now with Rediweld Ltd., Crawley.

G. R. Wooll (*Associate*), Vice-President, Genaire Ltd., Canada, has been elected President of Ardrox Ltd., a Canadian company recently formed by an association of Brent Chemical Products Ltd., and Genaire Ltd.

Diploma Course in Experimental Aerodynamics

The Training Center for Experimental Aerodynamics, Belgium, invites applications for the one-year diploma course in experimental aerodynamics from October 1959 to July 1960. There are no fees for the course and there are a number of student fellowships to cover living expenses.

Further information and application forms (which must be returned by 18th April) can be obtained from The Director, Training Center for Experimental Aerodynamics, 72 chaussée de Waterloo, Rhode-Saint-Genèse, Belgium.

Conference on Exploding Wires

The Geophysics Research Directorate will hold a conference on Exploding Wire Phenomenon on 2nd and 3rd April 1959, at the Somerset Hotel, Boston, Massachusetts. Papers will be given on both theoretical and practical aspects.

Further information is obtainable from William G. Chace, Thermal Radiation Laboratory, CRZCM, Geophysics Research Directorate, Air Force Cambridge Research Center, Bedford, Mass.

Meeting on Supersonic Transports, May 1959

The San Diego Section of the Institute of the Aeronautical Sciences is sponsoring a regional meeting on supersonic transports from 26th to 28th May 1959. The tentative agenda includes economic aspects of supersonic transports, design philosophies, systems design, operational problems and propulsion development.

Further information is obtainable from D. S. Macrae, Publicity Chairman, I.A.S.—San Diego Section, 3380 North Harbor Drive, San Diego 1, California.

Elections

The following is a list of new members and transfers of membership of the Society.

Associate Fellows

Philip Charles Akass
James Baker
Raymond Thomas John Ballard
Arthur John Cable (*from Graduate*)
Noel John Carew (*from Graduate*)
John Frederick Clarke (*from Graduate*)
Peter Norman Dent (*from Graduate*)
Thomas Patrick Doherty (*from Student*)
Reginald Stanley Emerson
Philip Pulsford Face
Albert Walter Fia
George Derek Forbes
John Evan Griffiths (*from Associate*)
John Robert Hair (*from Graduate*)
Patrick George Hall
Stephen John Taylor Harvey (*from Graduate*)
Brian Dutton Henshall (*from Graduate*)
Kenneth Nigel Hickman
William Robert Antony James (*from Graduate*)
John Irvine Lattey (*from Graduate*)
Francis Cyril Lowe
John Edwin Loxton (*from Associate*)
James Patrick Alexander Martindale
Joseph Thomas Morris
Charles Roy Pratt-Barlow (*from Graduate*)
Robert Victor Read (*from Graduate*)
Kevin Frank Rolph (*from Graduate*)
Cawas Meherji Sethna
Thomas Leo Shelton (*from Graduate*)
Henry Herbert Sims (*from Associate*)
Frank Roy Smith (*from Graduate*)
Reginald Smyth
Ernest George Sterland
Reginald Edward Taylor (*from Student*)
Dennis Reginald William Thomas
William Alfred James Thorn
Thomas Charles Edmund Tringham (*from Associate*)
T. Vargheese Vareed (*from Graduate*)

Associates

Stanley Francis Aldrich
Francis Evan Bisset
Jack Samuel Doyle (*from Student*)
Richard Robert Flute
Harry Halstead
David John Hermiston
Tirumale Rangaswamy Varadaraja Iyengar
Edward Emile Jansen (*from Companion*)
Maurice Hampden Satchell
William Richard Simons
Arthur William Southall
John Fielding Whitmore

Graduates

Jeffrey Bruce Allen (*from Student*)
William Richard Woods Ballard (*from Student*)
Martyn Howard Bolus (*from Student*)
Clive Reginald Brewer
Kenneth Brewster
David John Burns
Charles Christianson
Laurence Joseph Clancy
Maurice Edward Cox
Adam Andrzej Duch (*from Student*)
Michael John Evans (*from Student*)
Peter Eric Gunns
John Kenneth Haynes
John Derek Howells
William Peter Frederick Hurlow-Jones
Lloyd Ross Jenkinson (*from Student*)
Duncan Stuart Lennox
John Francis Anthony Nash (*from Student*)
John Stuart Nelson
John Clifford Penwill (*from Student*)
Anthony John Saint (*from Student*)
Brian Leslie Thorne
Alan Charles Norman Tucker
Terry John Walder
Donald Lyall Wilson (*from Student*)
Colin John Wood (*from Student*)

Students

Martin Charles Allen
Maung Ba Han
David Ivor Bausor
Iain Charles Douglas Cairns
Adrian Quentin Chapleo
John Payne Corfield
Joseph Craft
Alan Sydney Crawley
Peter Leonard Duffield
Douglas Trevor Endean
David Eshkeri
Roger John Evans
Brian Edward Gage
Allan C. Gilchrist
David Henry Gittins
Alan Clark Goldsmith
Eric John Holdcroft
David Howarth
Arthur Howes
Peter William Hunt
Hla Kyi
Kenneth Brian Loftus

Students

John Lomas
George Gordon Lucas
William Ian McFarlane
Thomas Anthony Marsland
Ohn Maung
Barry Mellers
Giovanni Mutevellian
Bryan Geoffrey Owen
David James Pollard
Geoffrey Pruden
Alexander Malcolm Reid
James Wood Thirsk
Godfrey Merlin Tromans
Kenneth Frederick George Urwin
Ian Alistair Vaughan
John Christie Vernon
Edward John Vickers
Robert Ward
Franciszek Wojewodka
John Wolstencroft

Companions

Brian Ernest Orr
Robert Harry Shaw

Mond Nickel Fellowships

Applications are invited for the Mond Nickel Fellowships for 1959. The main object is to enable selected applicants of British nationality and educated to University Degree or equivalent standard to obtain additional training and wider experience in industrial establishments at home or abroad. There is no age limit. Each Fellowship will occupy one working year and will be of approximately £900-£1200 value.

Full particulars and application forms can be obtained from The Secretary, Mond Nickel Fellowships Committee, 4 Grosvenor Gardens, London S.W.1.

Letter Translation

The Society occasionally receives letters in languages which the staff cannot translate. If any member is moderately fluent in any foreign language and is prepared to translate letters on a voluntary basis, it would be appreciated if he would send his name and the language offered to the Society's Librarian.

Journal Binding

Permanent Binding

1958 Volume (including packing and postage *in the United Kingdom*) .. .. .. £1 4s. 0d.
Previous Volumes (including packing and postage *in the United Kingdom*) .. .. £1 6s. 0d.

Journals, with a note of the name and address of the sender, should be sent direct to The Lewes Press, Friars Walk, Lewes, Sussex, and the remittance to the Secretary at the Offices of the Society.

Members are asked to be certain that the address to which they want their Journals sent is the same on their letters to the Lewes Press and to the Society.

Self-Binder Cases

Self-Binder cases of the "Easibind" type to hold 12 Journals are available from the Offices of the Society at 13s. 6d. each (including postage *in the United Kingdom*).

Changes of Address or Appointment

To assist in keeping the records of members correct and up to date the Secretary will be glad if all members will notify him as soon as possible of changes of address. He would also like to know of any change of appointment.

When notifying changes please give the following particulars:—

Name (in block letters) Grade of Membership
New Address (in block letters) Old address

New appointment.—Please give name and address of employer and position held.

Changes of address must be received *before the 15th of the month* in order to be effective for the Journal for the following month.

Preprints and Reports Received by the Library

The following C.A.I. Preprints, I.A.S. Reports and S.A.E. Preprints have been received by the Library:—

Canadian Aeronautical Institute

(A.G.M. 26th-27th May 1958)

Preprint No.

9/2 Some problems in airline turbine transport. R. J. Baker.
9/4 Search and rescue in Canada. J. W. Borden and W. G. Davison.
9/5 Airline planning for jets. J. A. Stern.
9/6 Future developments in air traffic control. I. G. Barrowman and B. Capel.
9/10 Electronics and Trans-Canada Air Lines. C. J. Campbell.
9/12 Non-destructive testing of aircraft materials. H. W. Grant.
9/13 Airline planned maintenance. R. J. McWilliams.
10/1 The Arrow weapon system and organisation for service management. D. W. Goss.
10/2 Some applications of Parkinson's Law. S. L. Britton.
10/3 Tooling approach to Arrow aircraft. E. B. Bragg.
10/4 Problems of precision production. F. W. Taggart.
10/5 The birth of a STOL landing gear. L. Vadeboncoeur.
10/7 Applications of a large-scale digital computer in aircraft design and development. A. O. Downing.
10/8 The applications of analogue computers to guided missile design. W. S. Kozak.
10/9 RCAF emergency runway barrier developments. W. M. McLeish.
10/10 Weapons systems ground support. J. F. Louv.
10/11 Naval aircraft carrier equipment. C. G. H. Daniel and N. A. Smith.
10/12 Some aerodynamic characteristics of wing-mounted lifting fans for VTOL applications. R. L. Wardlaw and N. V. McEachern.
10/13 VTOL transport configuration studies. F. C. Phillips and K. Irbitis.

I.A.S. Reports

(Presented at the 27th I.A.S. Annual Meeting, New York, 26th-29th January 1959)

(*Note*: These replace the "preprints")

No.

59-1 Hypersonic viscous flow over slender cones. L. Talbot, *et al.*
59-2 The cone-sphere in hypersonic helium above Mach number twenty. R. H. Johnson.
59-3 A study of creep collapse of a long circular cylindrical shell under uniform external pressure. N. J. Hoff, *et al.*
59-4 On the base pressure resulting from the interaction of a supersonic external stream with a sonic or subsonic jet. W-L. Chow.
59-5 Buckling of a cylindrical shell under a circumferential band load. D. O. Brush and F. A. Field.
59-6 The spectrum of vertical velocity near the surface. H. A. Panofsky and R. A. McCormick.
59-7 Piloting procedures and some human factors aspects of the VTOL-transition cycle of the X-13 aircraft. P. F. Girard.
59-8 Flight testing experiments with the tilt-wing aircraft. W. Z. Stepniewski and P. J. Dancik.
59-9 Proposed observations of the Martian atmosphere. M. D. Ross.
59-10 Self-contained electric-hydraulic accessory power unit. R. L. McManus.
59-11 Sources of helicopter development and manufacturing costs. J. B. Nichols.
59-12 Flight control-airframe system optimization. I. L. Ashkenas and D. T. McRuer.
59-13 The physicist's viewpoint: the function of universities in the aero-space engineering education. S. F. Singer.
59-14 Flexural vibrations of a thick walled circular cylinder according to the exact theory of elasticity. J. E. Greenspon.
59-15 Industry's viewpoint on the challenge of space technology to aeronautical engineering. G. Merrill.
59-16 An investigation of optimal zoom climb techniques. H. J. Kelly.
59-17 Two non-linear problems in the flight dynamics of modern ballistic missiles. J. D. Nicolaides.
59-18 Practical high lift systems using distributed boundary layer control. J. J. Cornish.
59-19 Some considerations relative to acoustically induced structural fatigue in a supersonic transport aircraft. G. L. Getline.
59-20 Fail-safe and fatigue development of the prop-jet transport airplane. A. J. York.
59-21 Thin doublers for fatigue resistant aluminum alloy structures. C. R. Smith.
59-22 Viability surveillance and data collection in biosatellite experiments. A. W. Hetherington.
59-23 What is specific impulse worth? E. R. Hinz.
59-24 Potentialities and problems of nuclear rocket propulsion. T. P. Cotter.
59-26 Comparison of current operational rotor systems and a rotor having floating hub and offset coning hinges. M. D. Marks.
59-27 Helicopter stabilization and handling characteristics improvement by mechanical means. M. Vague and C. M. Seibel.
59-28 Main rotor blade design and development. R. M. Kee.
59-29 Geophysical researches with the stratospheric laboratory. W. O. Roberts and G. Newkirk.
59-30 Guidance requirements of ballistic satellites. M. J. Stateman.
59-31 The determination of round-trip planetary reconnaissance trajectories. R. H. Battin.
59-32 Design of automatic flight control systems for manned space vehicles. A. J. Kelly.
59-33 Inertial guidance for hypersonic and orbital vehicles. G. W. Johnson and R. B. MacDonald.
59-34 Wave propagation through ionized gas in space communications. F. J. Tischer.
59-35 A shock tube investigation of heat transfer in the wake of a hemisphere-cylinder, with application to hypersonic flight. W. E. Powers *et al.*
59-36 Boundary layer transition on blunt bodies with highly cooled boundary layers. K. F. Stetson.
59-37 Heat transfer in separated flows. H. K. Larson.
59-38 Experiments on porous-wall cooling and flow separation control in a supersonic nozzle. L. Green and K. L. Nall.

S.A.E. Preprints

(Annual Meeting, Detroit, 12th-16th January 1959)

Preprint No.

2R Radiation shielding aspects of nuclear aircraft. N. M. Schaeffer and R. L. French.
4R Materials problems encountered in liquid propellant rocket engines. D. E. Roda.
7R Precise electric power for ground support of missiles. D. Ginsberg.
9R New fluorester lubricants for high temperature applications. E. C. Ballard and E. E. Sommers.
10R What is required of the aerial jeep? L. M. Hewin.
15R The monorail potential. S. H. Bingham.
18R Airline ground equipment functional requirements and design. W. H. Pitt.
2S Lockheed's Georgia nuclear laboratory. W. R. Rhoads.
4S High temperature solid film lubricants for uses above 1000°F. R. E. Crump.
5S Space trajectories and flight test objectives. J. W. Luecht.
10S Stability and control of the aerial jeep. M. O. McKinney.
15S The future of airline ground transportation. H. J. DeGraff.
18S Electrical ground power for commercial jet aircraft. R. L. Frantz.
2T Design and development problems of radiation and high-temperature tolerant electronic equipment. J. Gray Stuart.
4T Thermal insulation ceramic coatings. A. V. Levy.
5T Missile ground equipment. B. J. Meldrum.
7T Trends in support equipment systems. P. J. Burr.
9T Choosing rubberlike materials for use with synthetic hydraulic fluids. E. A. Webster and R. G. Larkin.
10T Aerophysics aerial platform VZ-7AP. R. W. Evans.
18T Early experience with ground equipment for B.707. P. G. Neelsen.
10U The Chrysler aerial jeep project. J. V. Gorton.
10V The development of the Piasecki "Sky-Car." F. N. Piasecki.

The Journal of the Royal Aeronautical Society

WITH WHICH IS INCORPORATED THE INSTITUTION OF AERONAUTICAL ENGINEERS

VOLUME 63 MARCH 1959 NUMBER 579

Presidential Reception—and Address

Four hundred members and guests attended the Presidential Reception which was held at the offices of the Society, 4 Hamilton Place, London, W.1, on Friday 13th February 1959. Members and guests were received by the President, Sir Arnold Hall, M.A., F.R.S., F.R.Ae.S. and Lady Hall, and their daughter, Miss Caroline Hall.

A buffet supper was served and the Salon Orchestra of the Royal Air Force, by kind permission of the Air Ministry, provided a background of pleasant music.

A small selection from the Society's collections of historic material and prints, and air mail covers, were on view together with exhibits indicating the work of the Membership, Publications and Technical Departments of the Society.

During the evening the President gave a short address by closed circuit television. Six television sets raised some 8 ft. from the floor enabled members and guests to see and hear the President throughout the building—three sets were located in the Library, two in the Council Room and one in Committee Room Two. The President spoke from the Secretary's office and this new form of Presidential Address proved a most successful innovation.

The following puts on record Sir Arnold's account of the work of the Society.

TODAY our Society has a membership of 10,550 distributed over the United Kingdom (8,400), the Commonwealth (1,500) and in foreign countries (650) (Fig. 1). Members take part in the activities of our main body, in the activities of its Branches, of which there are 28 in the United Kingdom (Fig. 2) and one in Singapore, and in the work of its Divisions in Australia, New Zealand and South Africa, each of which have their own Branches, to a total of 10 (Fig. 3). I would like to pay particular tribute to our Overseas and Branch Secretaries, who do splendid work on our behalf.

In putting before you an account of the state of the Society I would like particularly to draw your attention to some of the activities in which we are now concerned and indicate the remarkable volume of work which several of them entail. That the Royal Aeronautical Society is the oldest aeronautical body with an unbroken record is, I think, known well enough; it may be less generally appreciated that the Society has an undoubted claim to distinction for the contribution it has made in the past and is continuing to make now to the advance of aeronautical science and technology. Such advance is of interest to anyone connected directly or indirectly with the profession—not only to the engineers and scientists who bring it about or who use its products, but to those who build and sell and those who manage and organise, for without it all else will, in the end, come to a stop.

The need for a professional Society concerned with aeronautics arises for several reasons, and here are some of them. The arts and sciences concerned with the mechanics of air in motion are needed to so dominating an extent in aeronautics as compared with other branches of engineering as to justify a special body concerning itself with them. In 1930 we viewed the

Courtesy of "The Aeroplane"

The President shortly before beginning his Address.

aerodynamic scene from 0-300 m.p.h.; by 1940 we were looking towards 600 m.p.h.; in 1945 we started thinking of 1,500 m.p.h. and now 25,000 m.p.h. is by no means the limit; each of these régimes of flight has introduced radical new phenomena which we were concerned to understand. Next, the need for propulsion systems of a form peculiar to aeronautics has merited, and will continue to merit, the attention of a special body. In addition to all this it is often necessary to stimulate particular aspects of science and technology which

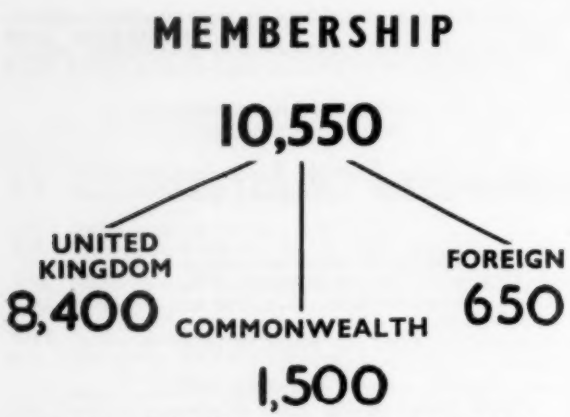

FIGURE 1. Distribution of membership of the Society.

aeronautical progress demands in forms far more advanced than their general development for other purposes would provide. In attending to these needs our primary aims are these; we stand for the advance of knowledge in aeronautical science and technology, and for its dissemination to all who can use it; we stand for the advance of scientific and technical education generally, and particularly those parts connected with aeronautics; we are concerned to set up standards of professional qualification, and of good engineering practice; and we are concerned with the preservation and assessment of the history of flight and of those who have taken part in advancing it. These aims, and the more important means we use to achieve them are shown in Fig. 4. I do not propose to deal with all these

FIGURE 2. Branches of the Society in the United Kingdom.

FIGURE 3. Overseas Divisions and Branches of the Society.

activities—to do so adequately would involve a long and perhaps somewhat laborious catalogue, even though they are all important and each a worthy contribution to your Society's work. There are some, however, which have facets which are less well known than others. I would like to start with our publications—these are important because they carry part of our work to all our members and also convey our influence to others outside the Society, both here and overseas.

We publish two technical periodicals, the JOURNAL OF THE ROYAL AERONAUTICAL SOCIETY and the AERONAUTICAL QUARTERLY. The proceedings of the Society were first published annually, an arrangement which continued from 1866 until 1893, but in 1897 the JOURNAL was started and it has an unbroken record of publication ever since. During this time it has carried many outstanding papers, including the first papers written by Wilbur Wright, Orville Wright and Frank Whittle. The Annual Reports which preceded the JOURNAL contained, in 1869, the first mention of the possible use of aluminium in aircraft, and in 1884 the first paper ever published on the possibilities of jet propulsion. I have no doubt that today we are publishing papers that will prove to have equal importance and influence. It is interesting that the demands of historians for the early

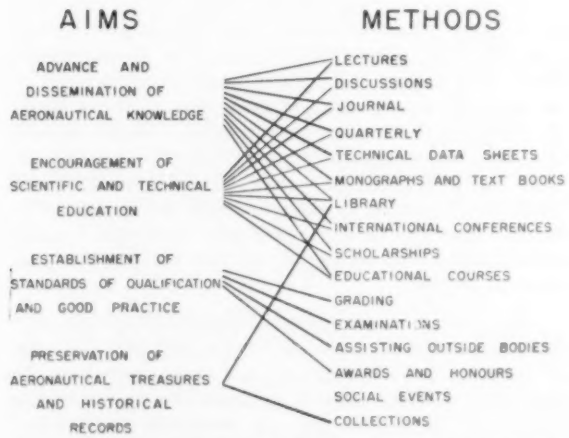

FIGURE 4. The aims of the Society and some of the methods used to achieve them.

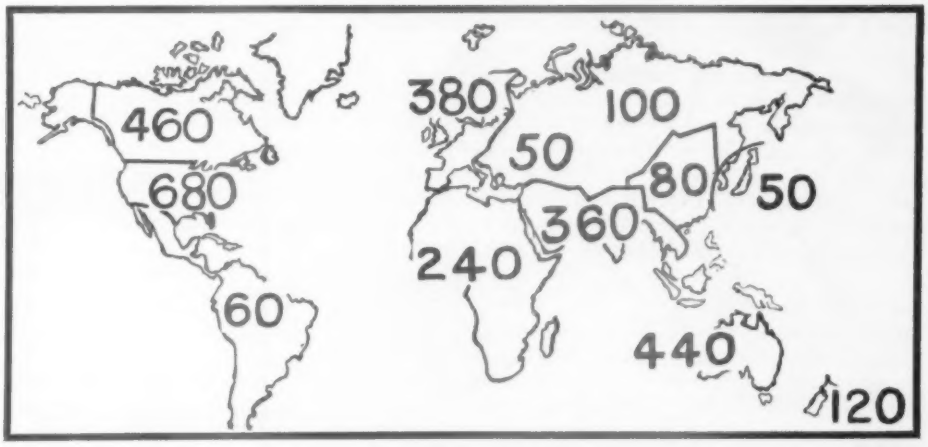

FIGURE 5. Overseas circulation of the JOURNAL. Each month 3,020 Journals go abroad to 75 countries.

proceedings of the Society have resulted in the reprinting of the Annual Reports 1866-1893 and the JOURNAL 1897-1911, originals of which are now very rare.

A copy of the JOURNAL reaches every member each month, but it may not be known how widespread is the demand outside the United Kingdom. Over 3,000 copies of each issue go abroad to 75 different countries. Some impression of their distribution is given in Fig. 5.

The AERONAUTICAL QUARTERLY is a more specialised publication, concerned, in the main, with advanced analytical papers. The Quarterly also goes all over the world—there are subscribers in 34 countries. The contents of this publication show very clearly the wide extent of the sciences to which aeronautical people find it necessary to give attention. Fig. 6 gives an impression of some of these. I believe that the Quarterly renders a considerable service by providing a medium for the publication and discussion of advanced research and by carrying specialised articles which might otherwise, for economic reasons, never see the light of day. Without advanced research subsequent development would be stifled and engineering robbed of its future progress.

The Society has published a number of monographs and textbooks. Our policy here has been to attempt to fill gaps in the literature produced by the publishing trade and so to make available to students material which might otherwise be denied them. We have published several specialised monographs on such subjects as materials and instrumentation, and we have issued textbooks on aircraft hydraulics, aircraft electronics and landing gear design. At the moment a bibliography on structural fatigue and a textbook on the theory of aeronautical structures are in preparation.

The Society has a full-time technical staff who are assisted and guided by the Technical Committees. These Committees are without parallel in knowledge and competence since the Society is able to draw for this service on its membership, which includes experts of the highest standing in every field of aeronautical activity. There exists at the moment Technical Committees covering Aerodynamics, Performance, Structures, Fatigue and Fuels and Lubricants. The Committees are charged with gathering and extending technical knowledge within their field, with sifting this knowledge, with disseminating what is of value by publishing data sheets and monographs and with the preparation of reasoned memoranda drawing attention to deficiencies in our present knowledge. The major products of this work are the Society's Data Sheets. These sheets are drawn up to provide correlated data and to present sound analytical procedures for use in design.

A typical data sheet is developed by the means depicted in Fig. 7, which shows in a particular case the sources of information considered and analysed by the Committee and the staff. Work of this kind represents a considerable contribution to productivity in the aeronautical profession. Fig. 8 gives some idea of this by comparing the cost of some typical stressing work as done by different means. Of course, such a comparison

FIGURE 6. *The Aeronautical Quarterly*: "Through the pages of the QUARTERLY today's research becomes tomorrow's aircraft."

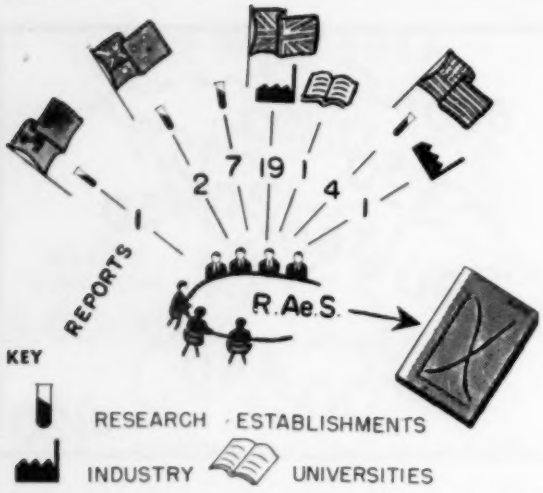

FIGURE 7. Collection of data from a wide range of sources, including Industry, Research Establishments and Universities, for the preparation of Aerodynamics Data Sheet 01.01.01.

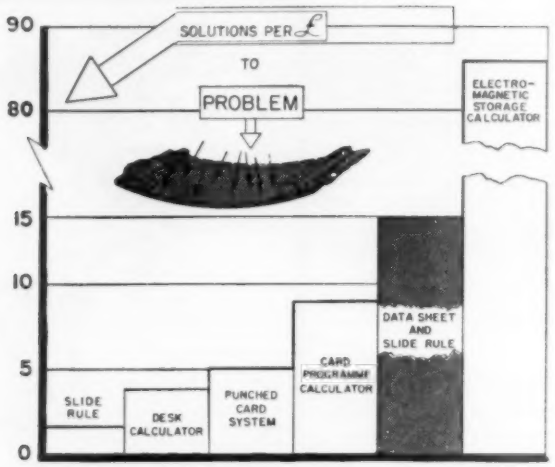

FIGURE 8. An example of the productivity of a Data Sheet.

FIGURE 9. International distribution of Data Sheets.

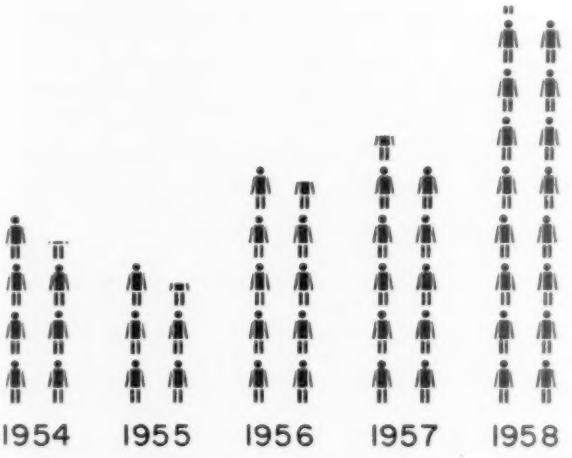

FIGURE 10. Annual increases in the number of new Data Sheet Units issued. (Each figure represents 20 units.)

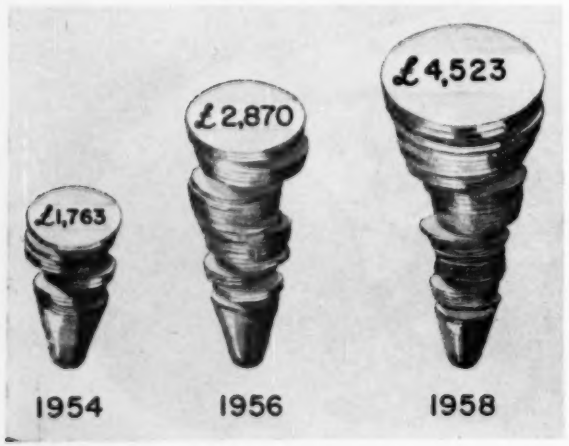

FIGURE 11. Annual revenue from the sale of Data Sheets.

FIGURE 12. The geographical distribution of Data Sheet users. (There are no users in the centres covered by the dark areas.)

is by no means general, but that our data sheets are recognised for quality and utility is demonstrated by the widespread use they have achieved, (Fig. 9), and by the rapid increase in the number of subscribers using them, (Fig. 10). In interpreting this figure, it should be borne in mind that a "Data Sheet Unit" is often a very large compendium—for example a unit of aerodynamic sheets comprises three volumes containing 208 individual working sheets. Fig. 11 shows how the revenue from the sale of data sheets has increased and Fig. 12 shows how their users are distributed geographically.

Our Technical Committees and staff are now at work on matters likely to be of importance in the future —and there are very many of them. For example, work relevant to the operation of high speed civil aircraft, to the handling of high density civil operations and to ballistic missiles and space vehicles is in hand. Such work covers aerodynamics, aircraft performance, new materials and new structural matters such as the stability of the pressure stabilised cylinders needed for rockets, satellites and space work.

If trade is brisk in the Technical area, so it is with the Library. We offer a "by return" service from our very comprehensive collection of books, periodicals and pamphlets, and large numbers of users avail themselves of it. In the past year there were 1,500 such loans—a "loan" often consisting of several items—in addition to the daily work of visiting users. Over 220 current journals from all parts of the world are available on the Library tables. Our collection of rare books and other historical treasures continues to grow—inevitably by "fits and starts" as opportunity presents itself. An interesting recent example is the acquisition of a 1742 edition of Robins' "New Principles of Gunnery" which is of considerable interest for the aerodynamic work contained in it, including what is probably the earliest recorded use of a whirling arm for aerodynamic experiments. Recently one of the television programme companies was surprised to find that we have an excellent collection of aeronautical poetry, material they needed for a schools programme. A continuous stream of borrowers make use of the extensive collection of lantern slides available in the Library.

We have very close, and I think very important, links with aeronautical bodies abroad. Not only do our publications and data sheets carry our work to every corner of the world—and with them an impression of the strength of British Aeronautics, with all that this implies—but we have the closest connections with our own Divisions, and with our sister societies in the Commonwealth—the Canadian Aeronautical Institute and the Aeronautical Society of India. We are in continuous touch with the Institute of Aeronautical Sciences in the U.S.A. with whom, together with the Canadian Institute, we share the Anglo-American Aeronautical Conference, and we have the most cordial relationship with our sister societies in Europe and particularly with A.F.I.T.A. in France. We are the British representative body on the International Council of the Aeronautical Sciences, a body with world-wide connections. We also take part in the activities of the Advisory Group for Aeronautical Research and Development under the North Atlantic Treaty Organisation, for which our Technical Department undertakes important work. These international connections are

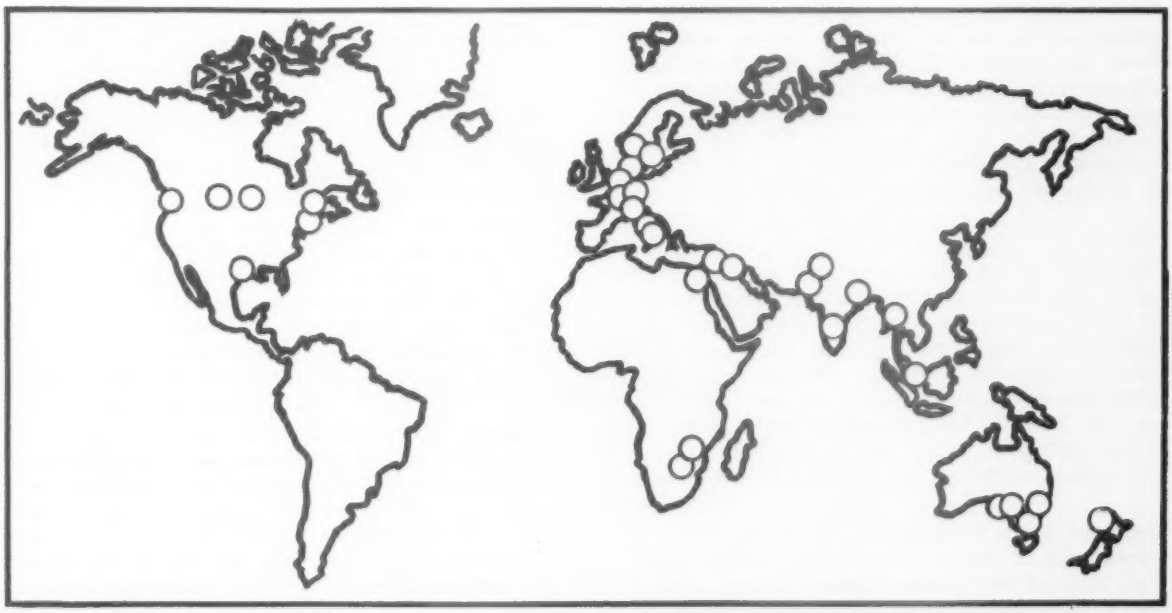

FIGURE 13. Showing centres throughout the world where the Associate Fellowship examinations of the Society were held in 1958.

one of the major means by which the British aeronautical profession is able to demonstrate its thinking abroad and to learn from others.

Our association with the Advisory Group of N.A.T.O. has led to the production, by our technical staff, of a handbook on aeronautical materials which provides data on the properties of the materials used for aeronautical purposes in all the N.A.T.O. countries. Such data, coupled as it is with a careful comparison of the different materials in use is likely to be of the greatest value when considering manufacture under license, and when undertaking the maintenance or modification of aircraft manufactured in other countries.

I think it may not be wholly appreciated by our members and others that the Society represents their interests on a wide variety of matters by nominating representatives on other Bodies. These important connections make it certain that the views of the aeronautical profession are given proper weight. At the moment our Society has representatives on about 40 Bodies, of which one-third are concerned with standardisation and standards of good engineering practice, another one-third with technical education, and the rest with a wide miscellany of subjects from the conduct of research laboratories to charitable purposes.

Looking back to Fig. 4 you will see that I have said nothing about a number of our activities—about our professional grading system with its very high standards, or about our examination system, although you may like to know that the Society now conducts professional examinations in 35 different countries; Fig. 13 shows the places in which we have examined recently. I have said nothing about our scholarships and awards, or about our own educational activities, which include the conduct of direct education by courses, such as the Air Transport Course, when such efforts are needed to fill the gaps left by the normal educational institutes. I have said nothing about our system of Sections and Groups, but I might mention that our Guided Flight Section has been renamed the Astronautics and Guided Flight Section and will now be responsible for seeing that the interests of our members in this important new field are adequately covered. Our Groups are a new arrangement which brings together small numbers of people interested in particular and often highly specialised aeronautical activities.

I have said nothing about our Lectures and Discussions, but on this point I want to draw your attention to the one outstanding need—a Lecture Theatre of our own. At a time when the breadth of our subject is widening rapidly and the demand for lectures and discussion is growing apace, it is becoming increasingly difficult to operate satisfactorily by using other people's premises. We have now evolved what is likely to be a satisfactory plan for adding a Lecture Theatre to our building here at 4 Hamilton Place, so preserving our present home, to which we are all greatly attached, while achieving the one thing that it lacks. This plan requires two things to make it reality—the first covers a number of legal consents from various authorities and the second is the will, coupled with the money. I am not yet in a position to tell you that the consents necessary have been given, although I am hopeful that they will be—the greater part of the work is already done. If they are, we will then have to approach our members and our friends outside the Society to obtain the necessary funds. The sum involved is by no means beyond what it is reasonable to expect to get. When we come to the point of making an appeal for this purpose then—if you are a member, bear in mind the value to you as a professional man of a learned Society advancing your art, representing your technical interests and providing the services I have outlined, and so assist your Office Bearers and Council to make our Headquarters all it should be—and if you are a leader of Industry, be mindful that your aeronautical products will go only so far as their technical excellence allows, and so far as your customers overseas have confidence in British Aeronautical Science and Engineering. If you are neither of these, but one of those who appreciate the extent to which this Country must rely on advanced engineering for its future and who recognise the strength that Bodies such as this can contribute, see to it that this scheme has your support.

Freighters—A General Survey

by

E. D. KEEN, B.Sc., A.F.I.A.S., F.R.Ae.S.

(Chief Designer, Sir W. G. Armstrong Whitworth Aircraft Ltd.)

The 32nd Main Lecture of the Society to be given at a Branch Centre, "Freighters—A General Survey" by Mr. E. D. Keen, B.Sc., A.F.I.A.S., F.R.Ae.S., was held under the auspices of the Birmingham Branch on 4th December 1958.

MR. F. F. CROCOMBE, F.R.Ae.S., President of the Birmingham Branch, opened the meeting by reminding those present that this was the second Main lecture to be held at the Birmingham Branch since its formation in 1944. The Branch had never been a large one and now numbered about 100 members drawn from local aviation enthusiasts and representatives of aircraft equipment and motor industry firms in the area. There was some longer-range support from Coventry and Wolverhampton but little from their own Birmingham University. Mr. Crocombe then welcomed the visitors, particularly the strong representation from Armstrong Whitworth and Blackburn and General Aircraft Ltd. He welcomed especially the President of the Society, Sir Arnold Hall, M.A., F.R.S., F.R.Ae.S. who would preside over the rest of the proceedings.

After thanking the Birmingham Branch for their hospitality, SIR ARNOLD HALL said that the holding of Main lectures at Branches had proved to be extremely popular and the practice should certainly be continued with enthusiasm. Introducing the lecturer, the President said that Mr. Keen had been a leading member of the Branch for a long time and was at present its Vice-President. Educated at the Regent Street Polytechnic, where he took a degree of the University of London, Mr. Keen had joined Armstrong Whitworth Aircraft Ltd. in 1928 and had been with the Company ever since. He became Assistant Chief Designer in 1949 and since 1955 he had been Chief Designer. In 1955 the Society had awarded him the Simms Gold Medal for a classical paper on "Integral Construction." His subject now was "Freighters," which was a part of aeronautical engineering that he had made particularly his own, first by study and later by putting his ideas into practice.

1. Introduction

Freighter aircraft designed for the civil market are practically non-existent. As discussed in this paper, expressed in terms of speed and comfort freighters are less glamorous and seem to have been neglected by operators and manufacturers alike.

It appears that, as a broad generalisation, civil operators have neglected freight as a useful contribution to their revenue. It is also equally true that those whose responsibility it is to send goods from factory to market, look no farther than the quoted air freight rates and dismiss them as more expensive than those for surface transport, without taking all the other advantages into account.

The distinguishing feature which characterises freight aircraft compared with those designed for passengers is the ease of loading and un-loading of goods, usually rather heavy, sometimes quite bulky and this profoundly influences the design. Conversely, converted civil aircraft are completely unsuitable for carrying freight. Professor Stanley Brewer of Washington University has stated that:

> "Very little has been done by the aircraft manufacturers to engineer better and faster loading and unloading of cargo airplanes. The airplane is one of the few vehicles of transportation that has not been able to separate its carrying unit from its power unit so that the expensive machinery of the motive unit can be utilized to a maximum degree. This is important since the operators cannot make money while their airplanes are sitting on the ground. Ways must be devised to keep them moving. It can and will be done by some manufacturer. That manufacturer will force the operators to buy his product, because they will have an advantage over their competitors."

For obvious reasons the author hopes that this forecast will come true!

2. Freighting Prospects

Forecasting future trends is a notoriously chancy business but Figs. 1 and 2 show that the air freight business, although small compared with passenger traffic, still shows a healthy increase. The 1957 figure of 11 per cent coincides almost exactly with the rate of passenger traffic increase shown on Figs. 3 and 4. The general pattern of traffic last year tends to suggest that there may be a slump in passenger traffic. Despite a temporary setback in the freight business, notably in the U.S.A. where some all-cargo carriers have found it difficult to carry on, largely, in the author's opinion due to operating unsuitable converted passenger aircraft, there are signs that the airlines are becoming aware that there is still a large untapped freight market. In the September 1958 issue of the "B.E.A. Magazine," Lord Douglas had the following to say about increase in freight traffic:

> "One side of B.E.A.'s business which has been doing rather well in recent months is our freight traffic. In the first four months of the financial year freight ton-miles were 13 per cent higher than in the same period last year. The revenue earned from freight now totals nearly £1·9 millions per annum

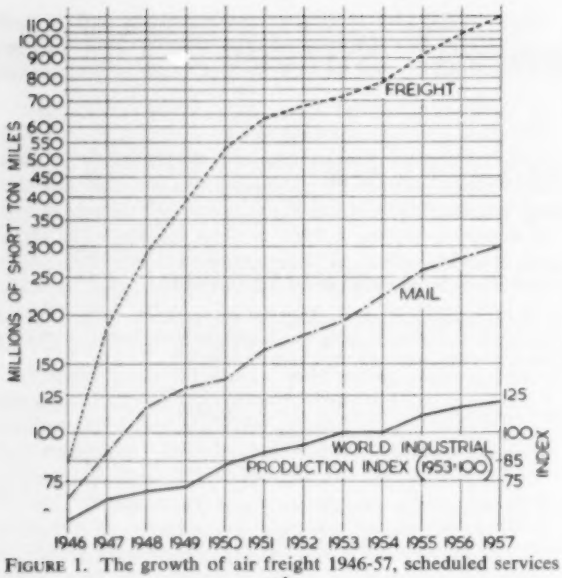
MILLIONS OF SHORT TON MILES
FREIGHT
MAIL
WORLD INDUSTRIAL PRODUCTION INDEX (1953=100)
INDEX
1946 1947 1948 1949 1950 1951 1952 1953 1954 1955 1956 1957

FIGURE 1. The growth of air freight 1946-57, scheduled services only.

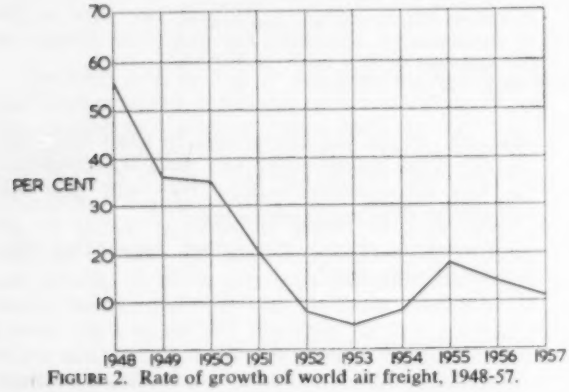

FIGURE 2. Rate of growth of world air freight, 1948-57.

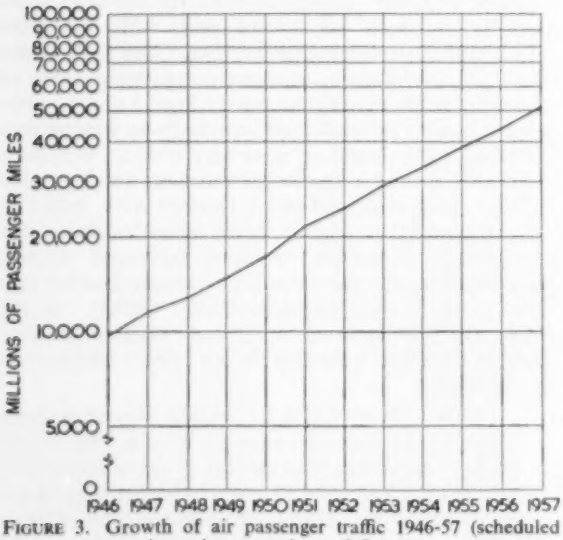

FIGURE 3. Growth of air passenger traffic 1946-57 (scheduled air carriers reporting to I.C.A.O.).

and should pass the two million pounds mark during the next few months. In March 1955 our annual revenue from this source was just over £1 million, so that it will have doubled in about 3½ years. In addition, progress has been made in reducing the one-directional flow of our freight which, at one time, was largely outward from this country. During the past year imports have been increased from 34 per cent to 38 per cent of the total traffic.

"The increases have, in fact, largely been the result of a great deal of hard work by the whole freight side of B.E.A.'s organisation. It is an achievement which deserves more credit than it usually gets—freight is too often over-shadowed by the passenger side of our operations. Now that passenger traffic is not doing so well, a healthy freight business is particularly welcome. It is making a valuable contribution to B.E.A.'s economy in our present difficult circumstances.

"Freight has always had the great advantage that it is less seasonal than passenger traffic and has its peak at a different time of the year. Last year we actually carried seven per cent more freight in the Winter than we did in the corresponding Summer six months. This is in marked contrast to the tremendous Summer peak in B.E.A.'s passenger traffic. The Summer passenger traffic is just twice that of the Winter. Freight thus helps considerably to mitigate B.E.A.'s peak/trough problem. It at present accounts for about seven per cent of our total traffic revenue and we must do everything we can to increase this proportion in the years ahead. At present, about 70 per cent of our freight revenue is earned on passenger services, the remaining 30 per cent by our freight aircraft."

The total freight carried during 1956 by 20 I.C.A.O. states is shown on Fig. 5. This diagram also gives the relation between freight and passenger movements and

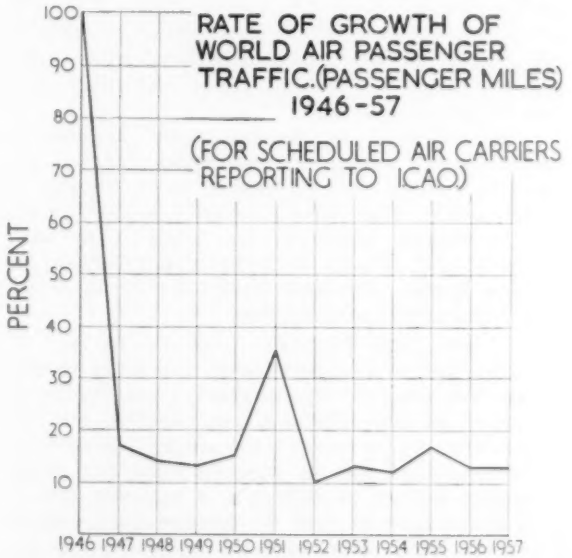
RATE OF GROWTH OF WORLD AIR PASSENGER TRAFFIC.(PASSENGER MILES) 1946-57
(FOR SCHEDULED AIR CARRIERS REPORTING TO ICAO)
PERCENT
1946 1947 1948 1949 1950 1951 1952 1953 1954 1955 1956 1957

FIGURE 4. Rate of passenger increase.

TABLE I

USE OF AIR TRANSPORT IN OVERSEAS TRADE

Total exports from U.K. 1956 £m.	*Total by Air* £m.	*Per cent.*
3,172	93	2·9
Total imports		
3,889	66	1·7

clearly indicates that areas with a growing economy with poor and difficult surface communications are using air freight very considerably.

Essential to any estimates of further development in world air freighting is the principle that traffic will expand as the freight rates are reduced. This has been shown in the recent history of air cargo and in many other industries in the period of their expansion. This elastic relationship has the greatest possible significance to air transport since the potential market is still so immense and because the development of improved aircraft offers further opportunity for expansion in the form of reduced operating costs and depression of the tariff.

The magnitude of this untapped market for air freight transportation to and from the United Kingdom is illustrated by Table I, which indicates exports and imports by air and by all means of transport.

During 1956 exports were flown from the U.K. to 150 different overseas territories. Only to France (15 per cent exports by air from U.K.) did the percentage of overseas trade by air exceed 10 per cent.

The total ton-miles of freight handled by all carriers in the United States, including railways, motor carriers, inland waterways, pipelines and airways, was of the order of 1,360 thousand million in 1956. Of this, the railways handled 656 thousand million ton-miles and motor trucks some 254 thousand million ton-miles. Air freight handled by all-cargo carriers amounted to only 336,900,000 ton-miles. In fact, this air freight is less than one three-hundredth of one per cent of the total freight handled by the transportation systems of the United States.

3. The Case for Air Freighting

The basic cost per ton mile of sending goods by air is higher in developed areas than by surface means, but this is far too simple a comparison. Besides the advantage of speed, which can be translated into definite financial savings, many other factors should be taken into account in assessing the value of air freighting. These can be listed briefly as follows:—

(*a*) Lower insurance rates.
(*b*) Reduced packing.
(*c*) Reduced handling.
(*d*) Less risk of damage and pilfering.
(*e*) Lower interest on capital value of goods in transit.
(*f*) Reduced stocks and warehousing at points of distribution.
(*g*) Reduction in "paper work."

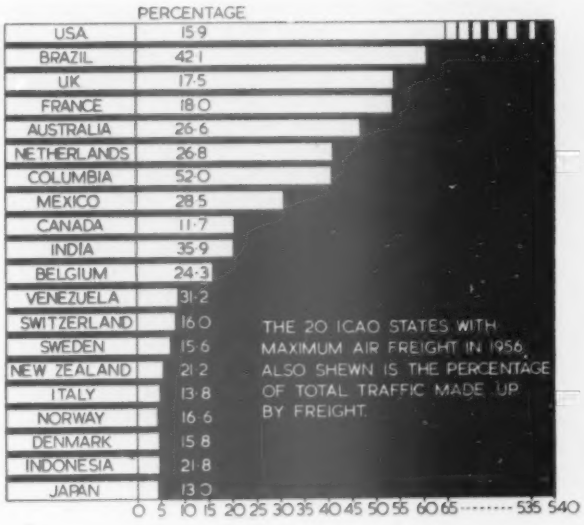

FIGURE 5. Freight carried in 1956.

The lower insurance costs are a matter of fact and prove that the goods receive better treatment than those conveyed by surface means.

The principal reason for this is the reduction of the number of handling operations involved in an overseas shipment, it generally being recognised that damage is most likely to occur at the docks.

A practical example of simplified and hence much less expensive packing, is shown in Fig. 6 which shows printing machines mounted in a light wooden framework and covered with a plastic material being loaded into an aircraft. Fig. 7 shows some automatic vending machines being loaded without any packing at all. Goods sent by air can be forwarded with a single waybill, greatly reducing the inventories necessary in a land-sea-land link.

An actual case history of consigning 20 kgs. of watches from Switzerland to Singapore shows how a considerable saving can be made by air freighting for articles of high intrinsic value.

		Surface	*Air*
	Documentation costs Swiss francs	31·50	18·50
Insurance	Surface rates 1·0375%	1099·75	
	Air rates 0·5%		530·0
Packing	Crating or air-cargo packing	7·0	3·50
Fr. charges	Pick-up charges at Swiss francs 19·05/kilo		3·50
	Zurich-Singapore	24·40	381·0
	Delivery charges		6·0
Interest charges	Customs duty (same for both) (money tied up due to transport and warehousing) time: 5% (air 4 days; post 45 days)	662·40	58·80
	Total cost	1825·05	1001·30
	Total time in transit	45 days	4 days
	Freight as A% of the value of shipment	1·72%	0·94%

FIGURE 6. Example of light packing.

FIGURE 7. Example of no packing.

As can be seen these advantages need to be gone into very carefully, taking into account all the factors involved as applied particularly to the business concerned. Many airlines with highly organised freight departments employ teams of experts who will advise interested firms on the suitability of air freighting to their particular problem. The motor car industry for instance can reduce considerably the number of spare parts held overseas if they can be replenished steadily by air freight and, for the larger repairs such as wings, bodies, and so on, can have the parts flown out to order without any necessity whatever for holding stocks. For businesses with a regular flow of freight, rates can be reduced by the negotiation of specific commodity rates on application to I.A.T.A., which already authorises a considerable list of such rates. For consignments of foodstuffs from London to Boston, Mass., of over 45 kgs., for instance, the specific Commodity Rate is 4s. 2d. per kilo., compared with the ordinary rate of 7s. 2d.

The foregoing considerations apply to goods which can be transported either by surface or air. Other factors may lead to creating new markets by the speed of air transportation. This applies to such commodities as flowers and fashion goods, newspapers, fish supplies to central areas of large continents and national schemes, such as Air Beef in Australia.

It was the conclusion of a recently published report of the Harvard Business School Research Division that the fullest use of air transport in the United States was made rather by the younger and more alert industries not yet tied to conventions of organisation and supply. It was found that many organisations had in fact no exact knowledge of important components of their production costs, such as warehousing and were, therefore, in no position to make a true comparison of air and surface transportation.

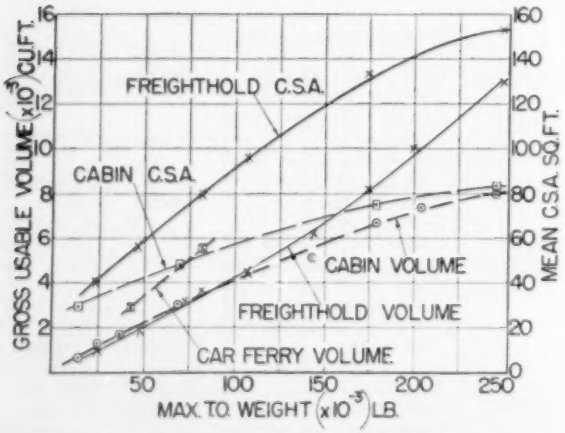

FIGURE 8. Cabin and freighthold comparison.

4. The Characteristic Dimensions of Freight Aircraft

The geometrical characteristics of the cabin for carrying passengers and those for carrying freight show quite marked differences. Whereas passenger cabins are in general long thin tubes, aircraft specifically designed for freight have short fat ones. Fig. 8 shows the cabin volumes and cross-section areas for a wide variety of the world's aircraft in use today plotted against maximum take-off weight. Considering that no other parameters are taken into account, these curves show incredibly little scatter. In general, aircraft with the higher take-off weights have higher cruising speeds and longer range (*see* Fig. 9). The curves in Fig. 8 show clearly that the main difference between passenger and freighter aircraft lies in the cross-sectional area arising from the greater fuselage width always demanded, since all specially designed freight aircraft have either been designed for military purposes in the first case, or can be readily adapted for military uses. They must, therefore, be capable of accommodating wide loads such as wheeled vehicles. The curve of freight hold cross-sectional area is particularly important because it shows that this parameter alone gives a

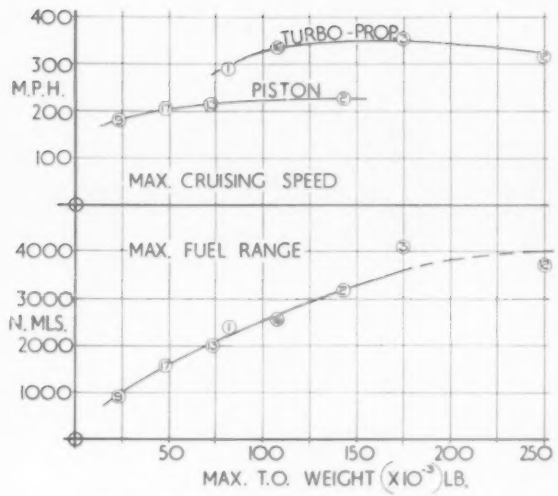

FIGURE 9. Speed and range of freighters.

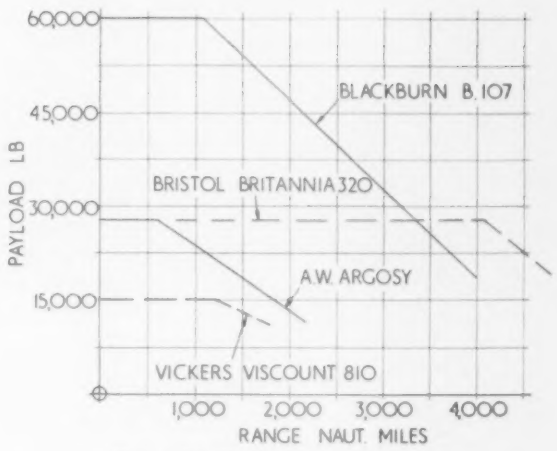

FIGURE 10. Payload-range comparison.

clear indication of the size of aircraft to carry equipment of specified dimensions. Thus the physical dimensions alone of military equipment required to be carried by air, dictates immediately what size of aircraft is required in terms of all-up weight and, therefore, cost.

The implications behind these simple curves are that freight aircraft are in a less glamorous class of aerial vehicle than their passenger counterparts. Their shorter, fatter and less streamlined fuselages will make them slower. To provide a clear freight hold they will be high-wing aeroplanes giving either long stalky undercarriages or bulges in the side of the fuselage, giving extra drag. The necessity for low floor height from the ground makes the shape of the fuselage depart from the ideal shape for pressurising which is a circular section and the freight floor has to cater for much higher loadings. This is possibly the reason why so very few aircraft have been designed for civil freighting and almost all have been designed for reasons of military necessity. The author is convinced, however, that specially designed civil freighters have a very important place in the field of civil transport and that the advantages to be obtained by specialised freighters, compared with the present practice of using converted civil passenger aircraft, will be such as to give a tremendous fillip to the air freight business.

Designers of freight aircraft have to take advantage of the payload range curve up to the take-off limit right down to the minimum range, the cut-off being solely determined by the fuel reserves, as shown in Fig. 10. The interesting point is that although precisely the same engines are used, the Argosy is designed to carry more payload at a slower speed than the Viscount and, in effect, utilises the lifting capacity of the engine rather than the speed potentialities of the power plant. This general characteristic is shown to give remarkably consistent curves for a large variety of aircraft as shown on Fig. 11 where maximum payload is plotted against maximum take-off weight. The obvious comment here is that these payloads do not occur, of course, at the same range or speed.

The potentialities of the freighter aircraft as a weight lifting device, albeit only being able to exert its maximum capabilities over a short range, are also demonstrated in Fig. 12. The density of the load carried is here expressed as the maximum payload divided by the gross usable volume for a large number of freight and passenger aircraft. This shows that freight aircraft load densities fall between 7 and 8 lb./cu.ft. and passenger aircraft between 4 and 6 lb./cu.ft. The special case of the car ferry, showing a low density, is shown by plots of the Bristol Freighter Type 32 (6A) and the A.W. 670 Car Ferry version of the Argosy (1A). Particulars of the aircraft used for Figs. 11 and 12 are given in Table II from the best available published data. The cross-sectional areas are average values computed from gross usable Freight Volume divided by freight hold length.

5. Freight Handling

The characteristic which determines the basic difference between specially designed freighter aircraft and converted passenger aircraft is easier access to the freight hold by providing as low a floor as possible and end loading. Both of these attributes are mandatory in the design of military freighters. Fig. 13 compares the access obtainable in four typical aircraft used for freighting. The ease of access to the Bristol Freighter compared to the DC-3, or the Lockheed C-130 compared with the DC-6 are only too obvious. No deep work study principles are needed here to assess the obvious advantages merely from a loading point of view, let alone the ability to accommodate bulky and lengthy loads.

Expressed in terms of airline economics the value of easy freight loading shows itself in two broad categories. The first is reduction of capital and maintenance, cost of ground equipment and labour cost. The second is expressed simply as reduced turn-round time.

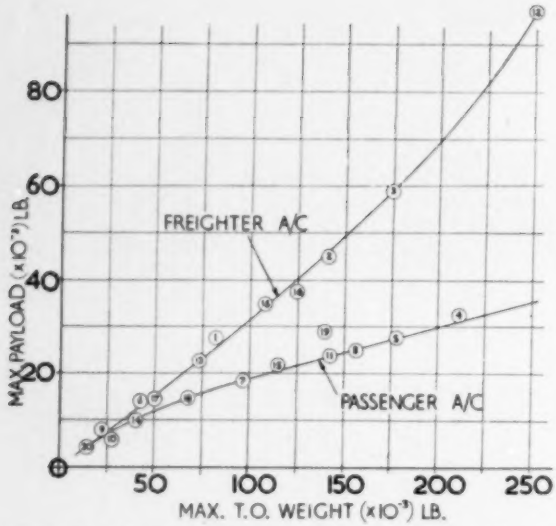

FIGURE 11. Maximum payload plotted against maximum take-off weight.

Aircraft time can be divided into the following categories:

1. Flying time.
2. Time on maintenance and overhaul.
3. Turn-round and transit time.
4. Idle time.

Assuming conservatively that an aircraft is idle for approximately 30 per cent of the year due to scheduling limitations, delays, and so on, then 6,000 hours are available annually for flight, maintenance, transit and turn-round.

TABLE II

AIRCRAFT NUMBER KEY FOR FIGURES 11 AND 12

		Max Payload	*All up Weight*
1.	A.W. Argosy	28,000	82,000
1A.	A.W. 670	28,000	82,000
2.	Blackburn Beverley	45,000	143,000
3.	Blackburn B. 107	60,000	175,000
4.	Boeing 720-020	32,000	212,000
5.	Bristol Britannia 320	28,000	180,000
6.	Bristol Freighter 170/31	14,000	44,000
6A.	Bristol Freighter 170/32	12,000	44,000
7.	Caravelle	18,250	97,000
8.	Comet 4B	24,550	156,000
9.	Caribou	7,600	24,000
10.	DC-3	7,000	25,200
11.	DC-7C	23,083	143,000
12.	Douglas C 133A	100,000	255,000
13.	Fairchild C-119G (Packet)	22,000	74,400
14.	H.P. Herald	10,160	37,000
15.	Lockheed Electra	22,000	113,000
		35,000	108,000
16.	Lockheed C-130	38,000	125,000
17.	Noratlas	14,330	48,500
18.	Vickers Viscount 810	15,054	69,000
19.	Vickers Vanguard	29,000	141,000
20.	Scottish Twin Pioneer	3,258	13,500

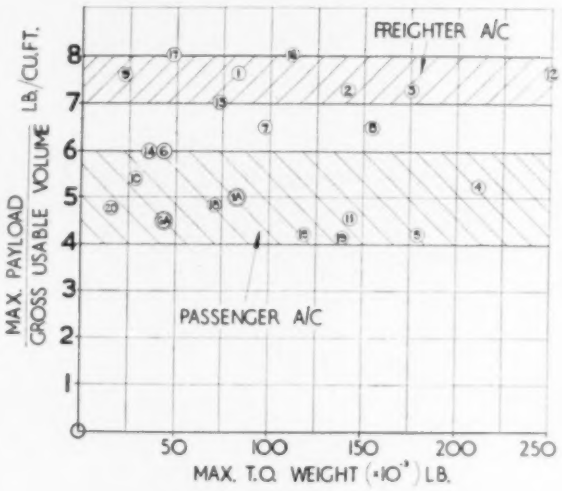

FIGURE 12. Loading densities.

Using up-to-date procedures, maintenance and overhaul time can readily be kept down to 25 per cent of flying time.

For scheduling purposes it is assumed here that a turn-round can be achieved in the time required to unload capacity payload and reload again plus an additional 10 minutes for the assembly of the necessary ground equipment and personnel. Based on these assumptions, the variation of annual utilisation with freight handling rate has been estimated for a freight load of 25,000 lb. in Fig. 14.

The rate of loading which can be achieved on converted civil aircraft with side loading without special aids, apart from forklift trucks, is about 250 to 300 lb./min. so that it can be seen that, particularly on short sectors, there exists a real potential economic gain if the loading process can be speeded-up.

There is a limit to which the loading can be speeded

AIRCRAFT	SILL HEIGHT	DOOR SIZE	HOLD LENGTH	PACKAGE LIMITS
DC-3	5′	5′-8″/4′-8″ X 7′-0″	30′	4″×8″×30′ 5′×4′×6′
170	4′-8″	6′-8″ X 6′-8″	32′	6′-6″×6′-6″ × 31′
DC-6A	8′-9″	6′-7″ X 10′-6″	68′	3′×3′×30′ 6′×6′×11′
C-130	3′-5″	9′-1″ X 10′-3″	41′-6″	9′ X 10′ X 40′

FIGURE 13. Access to typical freighters.

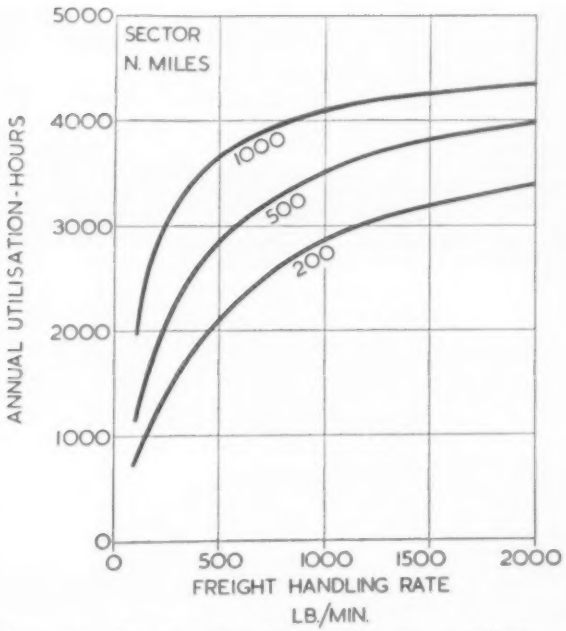

FIGURE 14. The effect of freight handling rate on utilisation.

up by merely providing easy access, however, and a case can be proved for making the loading equipment more sophisticated either in the aircraft or on the ground, or both. On the aircraft side, roller conveyor floors, palletising of loads and built-in winches all result in considerable decreases in turn-round time. Fig. 15 shows an estimate for a typical medium range freighter of the maximum airborne equipment weight, representing a direct loss in payload, which will result in a break-even direct operating cost figure. This sort of appraisal must be made for any proposed scheme since clearly unless the weight is less than that indicated on the curve for any particular operation it is not worthwhile. Airborne handling aids are particularly applicable to outback areas where it is uneconomic to provide sophisticated ground equipment.

The most comprehensive freight handling system in regular airline use in the world today is that devised for the air link between the railways of North and South Island in New Zealand. Here a supply of wheeled pallets, as shown in Fig. 16, are used to transport goods from the point of despatch to the point of delivery via trains, lorries and aircraft. Two pallets make up one lorry load and two lorry loads make one complete load for a Bristol Freighter. The aircraft floor is removed and rails substituted. Special ground equipment consists of two transversers, as shown in Fig. 17, one previously loaded with goods to be despatched and the other ready to unload the arriving aircraft. Fig. 18 shows the load being removed. The journey at present is 90 miles and the turn-round time 10-12 minutes. The handling staff required at the airport is very small indeed.

This system is called the "Cargon Loading System" and was originated, developed and patented by the late

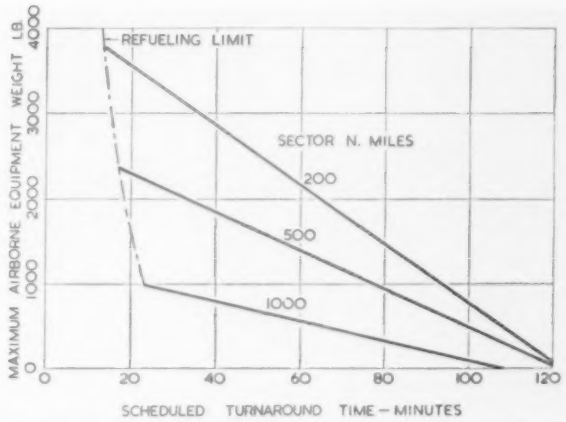

FIGURE 15. Airborne freight handling equipment, break-even weight.

Mr. T. O'Connell for the Straits Air Freight Express (S.A.F.E.) Company. The loading rate corresponds to something of the order of 2,500 lb./min. Reference to Fig. 14 shows the gain in utilisation given by such a system. The airborne equipment weight of the pallets, locking mechanism and rails over the normal floor is approximately 500 lb., well within the break-even value computed on the lines of Fig. 15.

This practically ideal transport system is ignored by civil operators in every other country in the world, except for the United States where certain holders of patent rights of the "Cargon" system are developing it. Such a system has been applied to a Lockheed Hercules and it is claimed that 35,000 lb. of freight can be loaded, or unloaded, in 40 seconds, a truly spectacular figure. Fisher and Ludlow are developing the "Cargon" system in the U.K. for use with road transport.

Coupled with their relative indifference to freight, air carriers seem to be disinterested in such developments largely because they are difficult to apply to the unsuitable aircraft they are operating. Once they can be persuaded to use aircraft properly designed for freight then we may see some uniformity and increased efficiency in their handling methods.

6. Design Philosophy of a Freighter Aircraft

The Armstrong Whitworth Argosy—Type Number A.W. 650 (Fig. 19) has been designed primarily to fulfil the needs of the civil operator to carry freight over medium stage lengths. A summary of the estimated performance is given in Appendix I. To ensure maximum possible utilisation at a period in history when operators are not quite sure whether they want to run all-freight services or not, the aircraft has also been designed to carry passengers—in tourist comfort either wholly or as a part of a mixed load.

After many preliminary studies had been made it was decided to build an aircraft which would fully exploit the load-carrying capabilities of four Rolls-Royce Dart (R.Da.7) engines, a power plant of proved reliability, universally popular and backed by a world-wide spares organisation. Choice of a turbo-prop

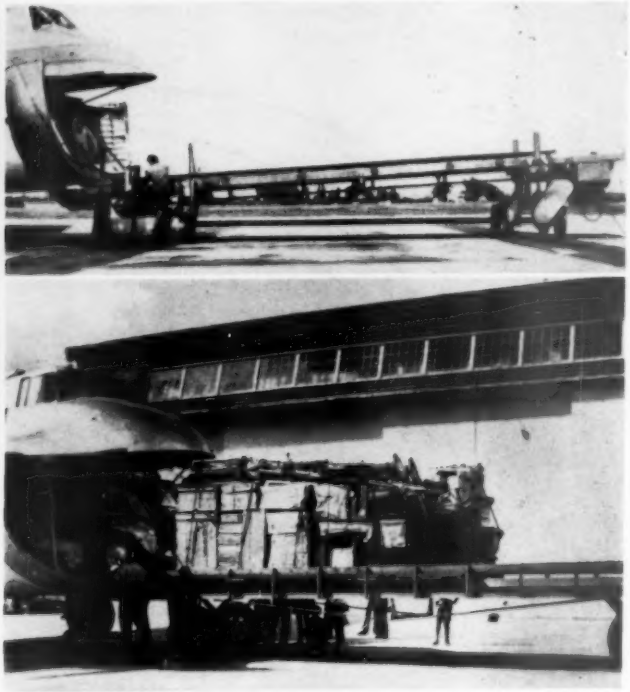

FIGURE 16 (*above*). Early cargon.

FIGURE 17 (*top right*). Traverser for cargon.

FIGURE 18 (*right*). S.A.F.E. cargon load.

engine demanded a pressurised cabin, not only to cater for passengers but to allow unrestricted carriage of the full range of air freight, including livestock. The design must be flexible and while primarily designed for the civil market must be capable of adaptation for military purposes with as little structural alteration as possible.

The first essential was a low floor and this was set at 4 ft., this being the average height of the bed of a lorry. The freight compartment must be free from restrictions and this fact, combined with a low floor, dictated a high wing aeroplane. The next parameter to decide upon was the height. The great majority of freight is, surprisingly enough, very dense. This is shown by Fig. 20 which shows the distribution of density of over 200 commodities packed for export. Assuming that the average capacity density of freight, from Fig. 12, is 7·5 lb./cu.ft. on the gross volume and that for one reason and another the usable net volume is 75 per cent of the gross volume giving an actual freight density of 10 lb./cu.ft., 88·7 per cent of the commodities examined fail to fill the available space. There is a crushing limit to the height to which dense articles in boxes can be stacked on top of one another which market studies indicated was certainly no more than 6 ft. The minimum height of the cabin was therefore fixed at 6 ft. 8 in. The cross-section of the fuselage was then the subject of intensive study. Due to the low floor a completely circular section—ideal for pressurisation—was not practical. The lightest solution in the circumstances appeared to be two circular arcs, intersecting at the floor line, as shown in Fig. 21. The section chosen accommodates:—

(*a*) Two rectangular stacks of cargo 6 ft. high with a central gangway in the section forward of the wing.

(*b*) Six abreast seating with 16 in. gangway.

(*c*) Maximum clear space in freight hold with seats folded.

Fig. 22 shows a section of the fuselage with the seats folded. End loading must be provided and early market

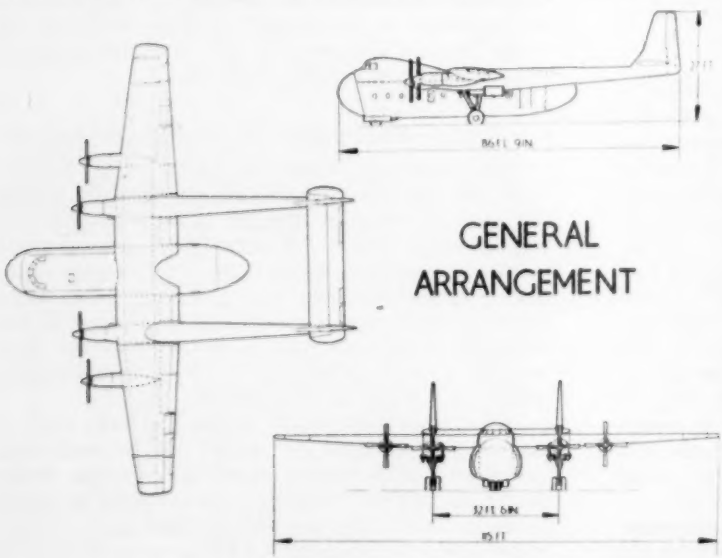

FIGURE 19. Argosy, general view.

surveys show that the ease and speed of freight handling would be greatly enhanced by providing a door at each end of the fuselage. The access diagram corresponding to Fig. 13 is shown in Fig. 23.

To provide doors giving end loading facilities to a pressurised fuselage is undoubtedly the most severe engineering problem on the whole aeroplane. For civil application it was agreed that these doors should be designed with the following attributes:—

(*a*) Sealing to preserve the internal cabin differential pressure is of paramount importance and should be simple and reliable.

(*b*) The size of the doors will involve large air loads during opening and closing in gusty weather and therefore an irreversible operating mechanism is essential.

(*c*) Although power operation is essential in the interests of speed, means must be provided to open the doors by hand if a source of power is not immediately available.

(*d*) The shape of the doors must give minimum drag and the weight must be as low as possible.

(*e*) The approach to the door sills with the doors open must be as unrestricted as possible.

(*f*) The space inside the doors must be used.

After very considerable research into every conceivable configuration of door it was decided to use the type shown in Fig. 24, a door like the top of an egg hinged at one side of the fuselage. This requires only a simple inflatable ring seal all in one plane (condition (*a*)). Side opening completely balances gravity forces

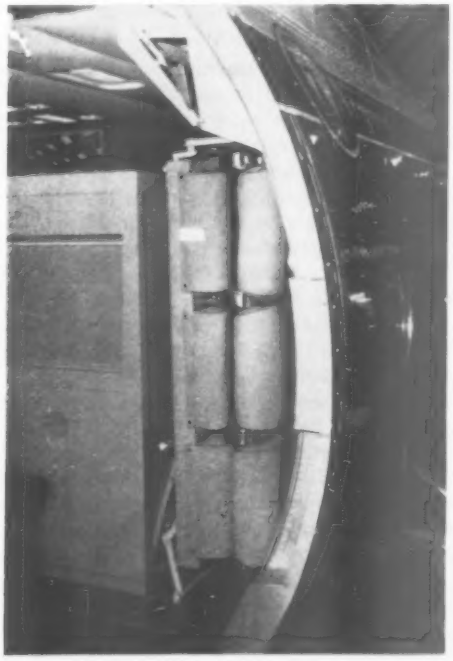

FIGURE 22. Argosy—Farnborough section.

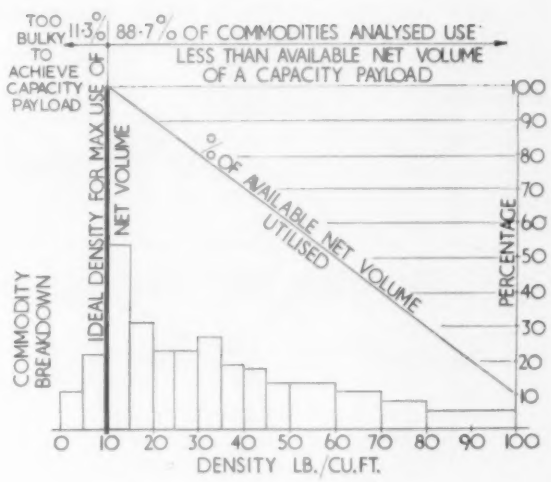

FIGURE 20. Freighthold volume utilisation.

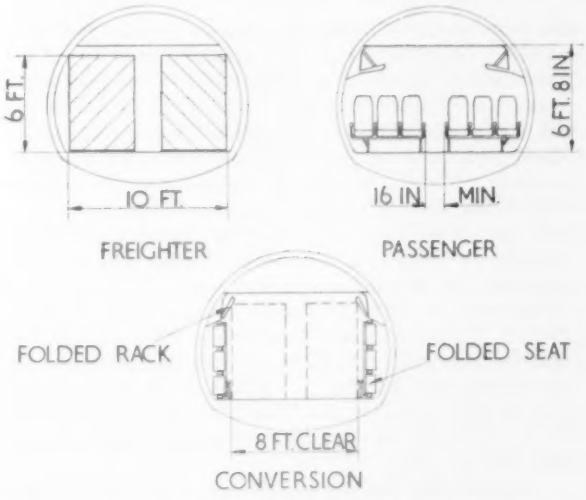

FIGURE 21. Argosy fuselage sections.

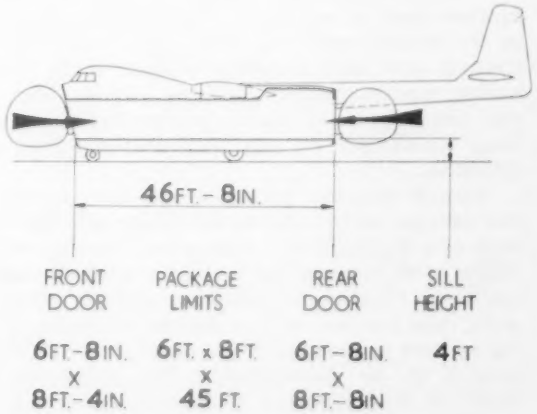

FIGURE 23. Access to Argosy.

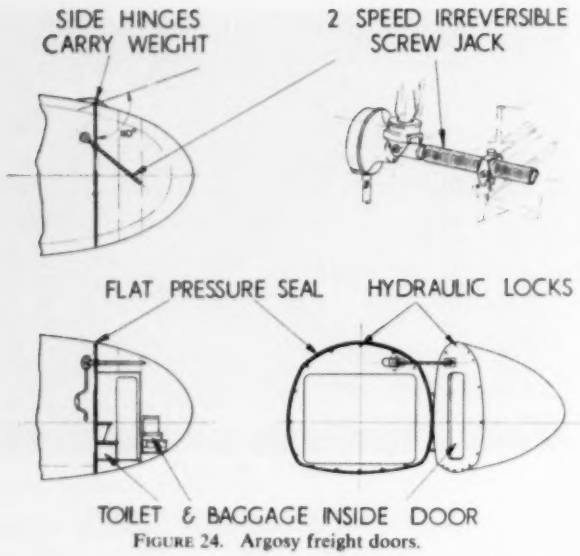

FIGURE 24. Argosy freight doors.

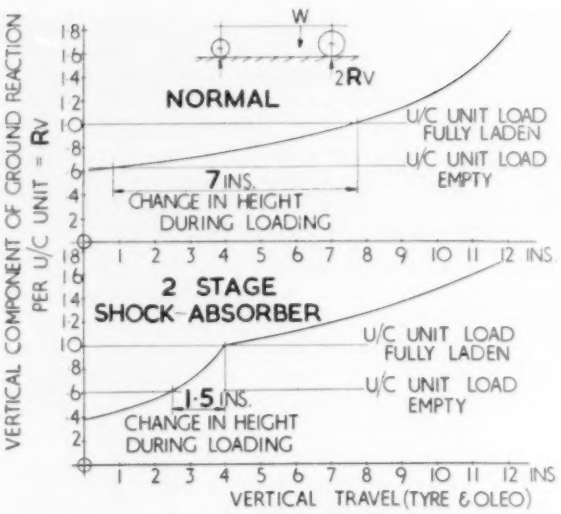
VERTICAL COMPONENT OF GROUND REACTION PER U/C UNIT = RV
W
2RV
NORMAL
U/C UNIT LOAD FULLY LADEN
U/C UNIT LOAD EMPTY
7 INS. CHANGE IN HEIGHT DURING LOADING
2 STAGE SHOCK ABSORBER
1·5 INS. CHANGE IN HEIGHT DURING LOADING
VERTICAL TRAVEL (TYRE & OLEO)

FIGURE 25. Main undercarriage static spring curves.

and gives minimum power for operation, making condition (*c*) possible. The door locks are operated hydraulically by means of a local system using a hand pump for manual operation. The shape of the door can fulfil streamlining requirements and the eggshell shape gives the lowest structural weight to resist internal pressure. Here, in the case of the rear door, it became evident that a direct conflict existed between this simplified conception and the military requirement of doors opening in flight and an integral ramp. Neither is required by the civil operator. At this point the advantages of the twin-boom configuration became evident, giving complete freedom to offer alternative rear fuselage door arrangements with the minimum of alteration to the aeroplane. Access to the rear door is also superior, fulfilling condition (*e*). Finally, the space in the doors can be used for crew and passenger toilets and baggage space.

Considerable thought has been given to keeping the floor level and at as constant a height as possible during the loading operation. The overall problem is a mutual one, really, because unless means of loading is standardised there is no object in keeping this dimension on the aircraft completely fixed. There is no doubt, however, that large variations in floor height during loading must be avoided. Loading over the front sill does not present quite such a problem but large loads being loaded over the rear sill can even present c.g. difficulties.

Aircraft with rear loading usually have a form of rear fuselage support and on the Argosy this takes the form of a hydraulic strut with a load limiting device, similar to the constant load pit prop now widely used in coal mines. Unless the aircraft is completely resting on jacks, there is no way of avoiding tyre deflections. Much can be done by attention to the shock absorber characteristics of the undercarriage. The travel can be shortened by introducing initial compression but this cannot be taken too far or taxying characteristics will be affected. A better overall solution can be obtained by introducing two-stage compression, minimising the travel over the static loading range of the aircraft. Examples of these types of characteristics on an oleo-pneumatic system are given in Fig. 25. Shock absorber travel could be eliminated entirely by releasing the pneumatic pressure from oleo-pneumatic shock absorbers and restoring the pressure by an engine-driven pump rather like a well-known continental car. This would also have the advantage of lowering the floor level for loading.

7. "Argosy" Variations

In these days of the emphasis on lack of money for aircraft development it is essential to spread development charges as widely as possible. In particular it has been stated as Government policy that the aircraft of Transport Command must have a civil application; in other words, there are indications that development money will not again be available for transport aircraft with a military application only. In the "Argosy" design studies it was considered, as previously mentioned, that there was a basic conflict between rear freight doors for civil and military uses. The tail boom configuration lends itself to providing alternative rear fuselages with the minimum airframe modification. Fig. 26 shows the fuselage of the A.W. 660 which incorporates rear doors which can be opened in flight and also, provides a larger aperture to allow effective access to the increased headroom available behind the rear spar for the carriage of large wheeled vehicles.

A highly specialised freight operation has become extremely popular in recent years, that of the aerial car ferry. The only aircraft used extensively for this rôle so far is the Bristol Freighter Type 32. Realising that a replacement will be required for this aircraft, in the not too distant future, specifications have been prepared by car ferry operators for a larger aircraft carrying at

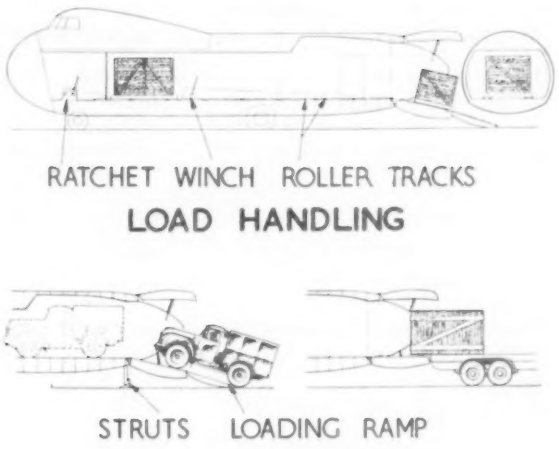

FIGURE 26. A.W. 660 military transport.

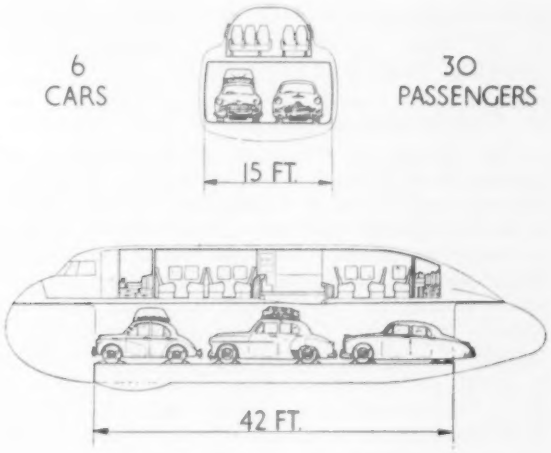

FIGURE 27. A.W. 670 car ferry.

least six cars in an attempt to bring down operating costs. Unfortunately, since these operations are over very short distances, a large number of cars can be moved by very few aircraft. Thus initial costs of such an aircraft designed *ab initio* would be high because development costs would be shared over very few aircraft. In the author's view the discontinuance in the future of this extremely useful service to the public is unthinkable. The A.W. 670 Air Ferry is one answer to this problem. A wide fuselage is substituted for the pressurised hull of the Argosy, as shown in Fig. 27. The ability to drive in one end and out of the other will greatly improve the turn-round time and reduce risk of damage. Pressurisation is unnecessary on the very short sectors involved and this variant too reaps the benefit of the large amount of development already expended on the basic type.

Only two short stretches of water have so far been the scene of extensive operations of this type, the English Channel and Cook Strait in New Zealand. There are many other similar situations in the world however, as shown in Fig. 28 and operations in these

FIGURE 28. Air ferry routes, world potential.

hitherto neglected routes could create a greater demand for this highly specialised type of aircraft, with a consequent reduction of first cost.

8. Conclusions

The carriage of freight by air is an expanding business which so far has not received the attention it deserves, and is being handicapped by the use of unsuitable aircraft primarily designed for carrying passengers in luxury conditions. Specially designed freight aircraft are needed whose attributes are easy access leading to rapid freight handling. Until the business is really on its feet such freighters should be capable of carrying passengers in reasonable comfort to ensure maximum utilisation. Ultimately, however, there will be a need for all-freight aircraft of greatly simplified form in which windows, passenger escape hatches and sophisticated air conditioning systems can be dispensed with.

ACKNOWLEDGMENTS

The author wishes to thank Sir W. G. Armstrong Whitworth Aircraft Limited for permission to present this paper and numerous members of the firm who have assisted in its preparation; Mr. Humphries, Midland Manager of K.L.M. Freight Department for his help in presenting the case for Air Freight; Airwork Limited for permission to use photographs of the S.A.F.E. operation and B.E.A. for permission to use Figs. 6 and 7 and extracts from their magazine.

APPENDIX

ESTIMATED WEIGHTS AND PERFORMANCE OF THE ARGOSY

T.O. weight	82,000 lb.
Average cruise speed (13,600 r.p.m.)	276 m.p.h.
(14,000 r.p.m.)	296 m.p.h.
Range with 20,000 lb. payload, No Reserves	1,600 statute miles
Ultimate still-air range	3,000 statute miles
Take-off field length (S.L. I.S.A.)	4,050 ft.
Take-off field length (4,000 ft.) I.S.A.+15°C	5,500 ft.
Minimum all engines operating take-off distance (S.L. I.S.A.)	3,200 ft.
Approach speed	117 m.p.h.
Landing distance (S.L. I.S.A.)	2,920 ft.
All engines operating performance ceiling (Gross weight 80,000 lb.)	22,600 ft.
3 engines operating performance ceiling (Gross weight 75,000 lb.)	20,200 ft.
2 engines operating performance ceiling (Gross weight 70,000 lb.)	14,800 ft.

GROUND MANOEUVRING CRITERIA

Tyre pressure	78 p.s.i.
L.C.N.	28
Maximum single wheel load	27,800 lb.
Minimum turning radius (steered)	36 ft.
Track	32 ft. 6 in.
Wheel base	25 ft. 5 in.

DISCUSSION

B. P. Laight (Chief Designer, Blackburn and General Aircraft Ltd., *Fellow*): Mr. Keen had, he thought, set out all the main problems and considerations which cropped up in the design of a freight aeroplane. Judging by his own experience he thought that Mr. Keen would not have found it easy to make a full detailed paper on the subject of freight alone. The freighter aircraft was still very much subservient to the passenger aircraft in the civil airlines and in fact the opening sentence of Mr. Keen's paper drew attention to this fact and it had been mentioned several times in the paper. Although there was a well established pattern of real business in passenger-carrying he thought there was a good way to go before the freight market was quite clearly and well established. The questions of just what freight would be carried and just what density, just what range and so on, could be answered by many different sorts of figures according to the particular operation that the aeroplane was to do.

The initial point on designing a civil freighter was to try and see as clearly as one could what market it was to meet. As to the markets, there was that sort of freight export which went on in civilised countries between places where there was probably very well established surface transport which constituted a very real source of competition to air freight; and there was the other kind—which many of them felt would grow in the fullness of time—the type of air freighting in undeveloped territories where there was almost no surface transport.

It was well to see this clearly in perspective when one thought first of all the amount of traffic between the centres of civilisation, according to Mr. Keen's figures for example; he thought it was a well known fact that the amount of air freight at the moment could be expressed by indicating that it could be accounted for if, for example, the passenger went on to the aeroplane with an extra forty pounds of baggage. This figure of forty pounds was only given to show that the actual ton-miles of freight was quite small compared with passenger ton-miles, because the passenger with his various facilities worked out at something over 200 lb. and was probably nearer 250 lb., so that the actual freight ton-miles added up to something like a sixth of the passenger ton-miles.

This equating of baggage with freight was even more closely borne out if one considered that much of this freight-carrying was in fact carried in the baggage holds of passenger aeroplanes and many airlines regarded freight only as the "jam on the bread," that was, they filled up their freight holds when they had not filled up with passengers. That got it into perspective, he thought, but it also showed, as Mr. Keen drew their attention to when he gave his very small percentage figure, that there was an enormous business that could be tacked on before the other means of transport even began to notice that air freight was stealing some of their markets. The volume of air freight was going up but it was going up in step with the passengers and not faster. Now it was quite provident to say that the airlines did not know their business and should get on and buy large numbers of freight aircraft and he did not dissent from that view if it could be made to stick, but one wondered why the market did not expand more rapidly and he suggested that one major consideration was cost.

Perhaps Mr. Keen would give them a line on what he thought about cost per ton mile, what he thou ht he could get it down to, what sort of business it wo d open up if he got it down to that much less than it now was for standard aircraft. This cost per ton mile was a figure that skidded all over the place; one saw figures quoted in the U.S.A. for four cents, one worked out figures of sixpence, eightpence, tenpence and the airlines quoted three shillings and sixpence, seven and sixpence; so there was plenty of room for variation in this and he would like to know what Mr. Keen's views were because he felt that if one got the cost down the business would be there.

He would also like to hear Mr. Keen's views on the place of freight aircraft in undeveloped territory. There were many ways of starting up activities of many sorts where minerals or natural resources existed but where there was no surface transport. Mr. Keen had put up some ideas that were rather new to him on the freight handling side and on the significance of turn-round time, although one knew of its vast importance.

He thought the term of freight handling really meant that one must not consider air freighting as just producing an aeroplane for freighting, it was really a transportation system to get goods from one point to another but until the whole pattern of the work was seen clearly it would not happen economically.

How elaborate did Mr. Keen think pallets should be? There were simple pallets, expensive pallets, there were boxes which folded, there was the Lockheed Speedpak where something like a large bath was buttoned underneath an aeroplane, or one could even go as far as the Fairchild system where, with an aeroplane very like Mr. Keen's they took the whole fuselage off and buttoned underneath a complete fuselage, so the aeroplane could be flown with or without this big box underneath as one wished.

As Mr. Keen pointed out, the Argosy covered freight and passengers, and obviously some penalties were paid for having a foot in the passenger camp. As a designer would Mr. Keen like to make a shot at what these penalties were? It would be nice to find someday a freight aircraft which said "to blazes with passengers."

P. L. Cronbach (Special Projects Engineer, Handley Page Ltd., *Associate Fellow*): The lecturer was mainly concerned with ranges up to 2,000 miles, but there was a vast volume of freight carried across the oceans of the world. Mr. Keen mentioned the question of watches from Switzerland, they went a long way, they could go straight to New York. There were other types of load which came from Europe straight across the Atlantic. Freight aircraft of this type would inevitably be large and costly, and they believed there was a place for a combination passenger/freight aircraft properly designed to enable the aircraft to be economic both as a passenger aircraft and as a freight aircraft. There was criticism at the present time of the size of aircraft operating the Atlantic routes, and much shaking of heads about the possibility of filling them. If they could not be filled with passengers it was much better to fill them with freight or a combination of both. Present aircraft, as had been pointed out, were not very convenient for this. They believed that efficient aircraft could be designed for combined operations and these would help the passenger by giving him cheap fares and allow the freight to operate at economic prices.

It seemed unlikely at present that one could achieve cost figures for freight which were low enough to give the market expansion necessary for a new full freight aircraft to be economical. Direct operating costs of five cents per short ton n. mile were being quoted by American authorities as being the target to achieve this.

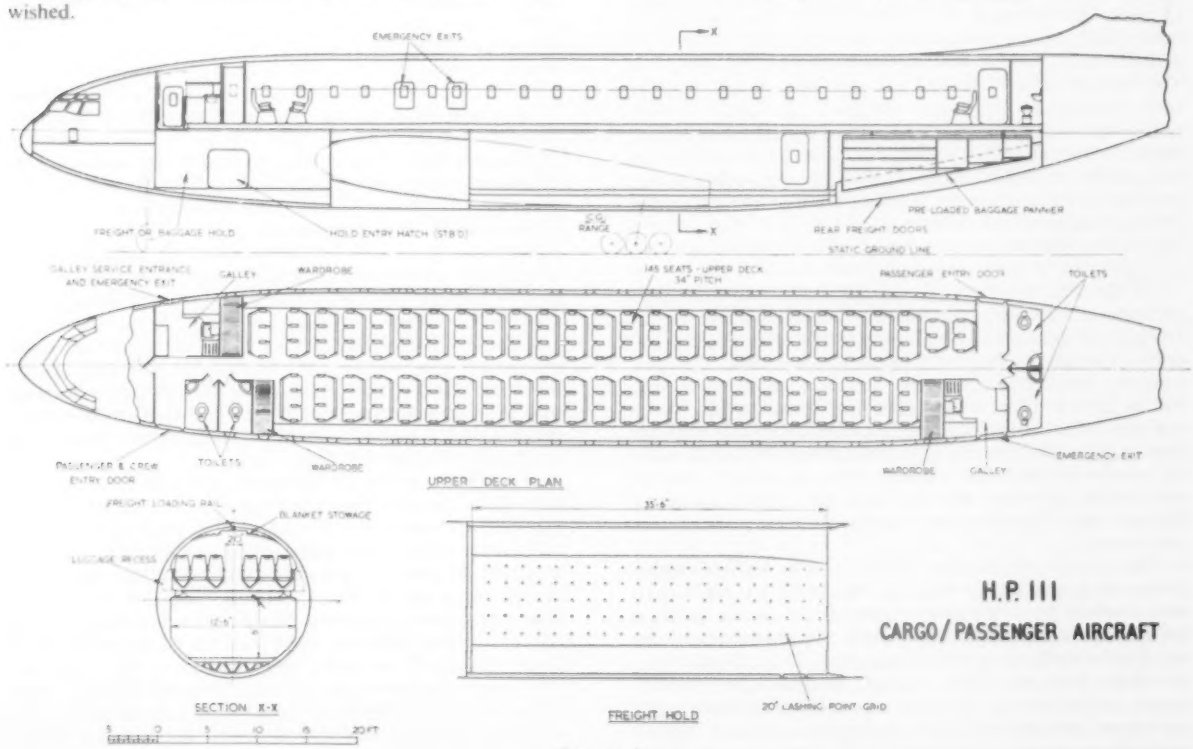

FIGURE A.

The layout in Fig. A had been worked out in some detail and showed what could, he thought, be done. It was a two-deck arrangement in a fifteen foot six inch diameter fuselage, which had not a bad shape. The lower compartment was six foot high, 30 ft. long and 10 ft. wide, and was disposed about the centre of gravity for this aircraft (this was comparable with the size selected by Mr. Keen in the A.W.650 type). Such an arrangement enabled one to have the upper deck in which passengers would not know they were in a freight aeroplane and at the same time, gave full facilities including rear doors for a lower freight deck.

Since it should be possible to predict passenger loading fairly accurately, the amount of freight capacity would be known and the aircraft kept fully loaded winter and summer.

If the large aircraft could be kept filled and hence economic, further reductions in fares and freight rates could be achieved by laminarisation using suction.

On relatively long ranges they believed there must be aerodynamic efficiency and hence a reasonable aerodynamic shape. Once this was achieved the turbo-jet became as cheap as the turbo-prop aircraft.

Did Mr. Keen believe that seventy pounds per square inch in the tyres was really low enough for operations from undeveloped aerodromes?

L. Haworth (Rolls-Royce Ltd., *Associate Fellow*): In these days of supersonics and sputniks, a paper on freighters might seem to some people a little slow and rather uninteresting. Mr. Keen had shown that this was not so; glamour and interest were not necessarily synonymous.

About this time last year he was in South Africa and was asked several times:— "Why don't you people in Britain make a light aircraft?" They were able to point to the need for such an aircraft in the Dominions and many parts of the Empire and that they had to procure such aircraft from America. He had said he thought it was because Britain herself did not have much need of such aircraft and people did not think that such a market might exist. If this were so it was perhaps really rather stupid. After all, their ancestors, particularly in Birmingham, made and sold a large number of three-legged cooking pots and so on, for the far flung corners of the Empire, although those articles were not much used in this country. When one looked around the city of Birmingham they seemed to have done rather well out of it.

In the United States, he was surprised a few years ago to learn of the very large market for executive aircraft. He had no figures but was told that there were more aircraft privately owned and operated in the U.S.A. for company executive travel than were owned and operated by all the airlines in the country. That really was a business which might be worth going after; but one saw little sign in this country that anyone was trying to make an aircraft to meet that market. They had seen, particularly in the past year, how well one could do if one could capture even a few per cent of the American market for motor cars.

There was a time when, if one were at sea and saw a plume of smoke on the horizon, one could lay ten to one that it would be a British ship making the smoke, and, on the average win money. He thought that those were really the days of Britain's greatest influence. So he thought that Mr. Keen had done them a service and had done it for a rather special reason. He took it as obvious that they could no longer compete with the two giants in every sphere, particularly in the military sphere and in respect of the rather more glamorous and costly aircraft. One heard a good deal of talk in this country about Britain making a supersonic air liner for the Blue Riband service of the Atlantic and so on. That was what he meant by glamorous. Because the two giants had their eyes on high performance, prestige and glamour, they had, he thought, in Britain an opportunity which Mr. Keen had showed them how to grasp. If they did grasp the opportunity in the way Mr. Keen indicated, the giants might think them somewhat slow and a bit unspectacular and many people in this country would think they were rather foolish; but there was too much shouting in Britain today about Britain leading the world in this, that, and the other way.

He would like to quote a little poem by a Chinese author, the feeling behind which illustrated his theme:—

> "There is the wisdom of the foolish,
> The Gracefulness of the slow,
> The Subtlety of stupidity,
> The Advantage of lying low."

J. F. Cuss (Gloster Aircraft Co. Ltd., *Associate Fellow*): About two years ago the Cheltenham and Gloucester Branch had a lecture from a man who had visited Russia and gave an idea of the way in which air services were developing there, and if they could just think of the word Freightliner and not entirely of freight at the moment, it seemed to him that there was a very good case for trying to do some business. The U.S.S.R. obviously treated each of the Air Stations as a sort of bus stopping place. They just gathered there when the aeroplane came in, got on it, and went off most unconcernedly. While it was possible that in the U.S.S.R. they were devoting most of their attention to sputniks and to long range missiles, they might not have given all the thought, which they might have done, to this short haul job. As far as he could make out, many of the aerodromes were situated in relatively undeveloped places with no particular railways, no particular roads and the only way of going from A to B was by air. He did not know whether Armstrong-Whitworth had been into that market or not. He expected if they sold them a few they would copy them and that would be that.

He wondered about the possibility of some rather specialised cargo along the lines of very long girders or bridge work, the sort of thing which had to be got to remote places away from roads or rail heads. Would it be possible to fly the Freighter with both the front and rear freight doors left off, with the load sticking out both ways? It might be possible that the cruising speed would need to be reduced.

On the question of a longer range for freight to cross the Atlantic; he did not think it mattered if it took freight a few more hours than the high-speed passenger air liners and he imagined there might be scope for additional tankage in the fuselage, if it seemed worth while. Would the author give his ideas on this?

D. L. Dobson (British European Airways): Their experience in B.E.A. over the past financial year was that 84 per cent of the revenue derived from traffic was from passenger traffic and only 6·2 per cent came from freight. Sixty-six per cent of this 6·2 per cent was carried on passenger aircraft, in other words it was the "jam on the bread." That was always something which the airline was looking for; to get this additional revenue when the passenger load factor was small and they could "make weight." It was interesting to note—incidentally they did have these passenger peak periods when they were up in the clouds in the summer and in the winter were down in the depths —that 7 per cent more freight was carried in the winter

than in the summer, which from the airline's point of view was a good feature, if they could bring a balance by freight.

He agreed that the turn-round time on the ground was an important feature. In B.E.A. they would, in a short time, be using the Vanguard, which was a bit like the Handley Page suggestion but, apart from the fact that they had one hold forward and one hold aft of the wing which helped considerably in loading, they had not quite the same c.g. worry. By loading the front end of the front hold and the rear end of the rear hold and building up the freight in this manner they did not have a great deal of trouble. They had considered pallet loading, but as Mr. Keen suggested, tried to make this as simple as possible. In trying to improve on the loading of the aircraft they had endeavoured to speed the actual loading operation and to that end, on paper at least, had designed what they termed a "multi-purpose vehicle." This was a forward-loading vehicle which approached the aircraft head on, had an offset cab and a platform with conveyor rollers. The intention was that they could elevate the platform of the vehicle from round about three feet nine to twelve feet. The reason why it was called multi-purpose was that it could be used for loading the lower holds of the Vanguard, which were approximately about 4 ft. 8 in. from the ground and go up to the height of the top cabin to lift the catering equipment. They hoped that in so doing there would be a decrease in the actual turn-round time both in the loading of freight and for the services in the cabin. They were fortunate that in the initial requirements they stated that the doors of the two holds be mid-way in each hold, which they considered advantageous on multi-sector routes; in other words, where they had to go from A to B, off-load and take up partial loads at B, move on to C, do the same thing and on to D.

This vehicle in itself was capable of utilising pallets; they had built one mock-up pallet, basically an aircraft pallet, which was capable of being loaded in the freight shed. It could be lifted by the normal fork lift on to the top of the multi-purpose vehicle or any other vehicle and then transported directly to the aircraft. On a multi-purpose vehicle it would only require pushing along the conveyor rollers until it came to the sill of the aircraft, the platform having been raised to the necessary height. It was then pushed on to transveyors, which in point of fact were spheres let into the existing recessed channels in the hold floor of the Vanguard. These members which were fitted in way of the doors, allowed the transfer of direction from the thwart-ship movement to the forward movement in the hold, just on spherical rollers. The pallet went from that point on to ordinary rollers which were let into the channels of the aircraft, then pushed into the position which it had been allotted in the hold. The size of the pallets had been kept down to the extent of the hold floor width of the aircraft and they had found, by manual loading without any power, that they could comfortably push a 700 lb. load in, either by fork lift or off the vehicle, in one minute, and they considered that a reasonable condition to apply. Each hold was capable of taking six pallets. To assist in the loading and, using a fork lift where the more expensive vehicle would not be available, they had introduced special shoes on the fork lift and all that happened was that those were clipped on to the actual arms of the fork lift and, having rollers, one could slide the fork lift underneath the pallet which was recessed. The fork lift with pallet moved up to the aircraft hold which had clam-opening doors and the overthrow of the shoes allowed one to push the loaded pallet onto the transveyors in the threshold of the hold itself.

Simplicity was aimed at all the way along. This was purely in the development stage just now and they were not satisfied that, whereas they could save time in the individual loading, the loading of individual pieces by collecting them on to pallets was going to be a really commercial proposition. They could not state in any one route pattern how many pallets might be required to fit into a hold, because route freight loads varied considerably.

He would like to take up a point in the lecture in relation to the aircraft utilisation. It was broken down into four sections: flying time, time on maintenance and overhaul, turn-round time and idle time. He thought it was incumbent on the operator, whoever he might be, to keep the proportion of turn-round time well in focus, because if one could not utilise the potential saving in turn-round time, it might only add to the idle time. That was a responsibility of which Mr. Keen had full knowledge and they hoped as the freight potential developed it could be utilised.

J. O. N. Lawrence (Joseph Lucas (Gas Turbine Equipment) Ltd., *Fellow*):

He was interested in the comment that "the aeroplane is one of the few vehicles of transportation that has not been able to separate its carrying unit from its power unit so that the expensive machinery of the motive unit can be utilised to a maximum degree." Had Mr. Keen any thought of the revival in the ultimate of glider trains as employed at the Arnhem landings? A few years ago he was privileged, when he was visiting the United States, to listen to a lecture at the Bendix supervisors club by the Vice-President and General Manager of the freight side of United Airlines. Here was an operator specifically interested in freight carrying, who was making the argument that his operations would be far simpler and his profit margins greater if only he had a purely freight aircraft to which he could devote his attention, without being bothered with passengers; they only complicated matters and made things more difficult. He thought that that was a report from an operator which Mr. Keen would be interested in.

On the subject of costs, the great success of the various tourist arrangements for civil aviation had now been acknowledged to have been a vital factor in keeping the industry going in the past year, despite the active opposition to the idea at first. There was every reason to believe that the air freight picture would be governed by the same laws and thus Mr. Keen's basic philosophy behind the Argosy concept had already received practical confirmation. One could see from the comparisons in the paper between the converted civil types and the two freighter concepts what lower operating cost would accrue by this idea.

Mr. Keen mentioned that the freighter aircraft would be in a less glamorous class with shorter fatter and less streamlined fuselages. Later he declared that the density of the freight was normally much heavier than the optimum. This meant, he took it, that when the aircraft was loaded to its maximum weight figure there was still lots of fresh air and space in which, for instance, toy balloons filled with hydrogen or perhaps better, helium, could be stored. While obviously there would be certain peculiar shaped loads which could be more easily accommodated in aircraft with large fuselages, did not this argument in fact suggest, that for most flights a sleeker freighter aircraft could be used with advantage as far as drag was concerned?

Mr. Laight mentioned air freightage and surface travel. He believed however that in Alaska and Northern Canada,

where aircraft were the only way to begin with and a lot of the heavy work was done, factories were more or less transported there by air; now in order to get the minerals and goods away from those parts they were starting to open up more conventional surface routes. Was this perhaps because Mr. Keen's Argosy had not yet arrived and the trend would alter later?

H. R. Watson (Armstrong-Whitworth Aircraft Ltd., *Associate Fellow*): One of the main themes of Mr. Keen's paper was that they would be able to increase freighter traffic when they had an aircraft which was really designed to suit this purpose, but Mr. Keen went on to tell them that freight was growing now at a considerable rate. He felt that perhaps the presentation in Fig. 2 was a little too pessimistic in that it showed a curve which appeared to be going down hill all the way. What it really meant when one inspected it less casually was that the growth expressed in terms of 1947 values, amounted to something like 530 per cent. This presentation also meant that if one had a bumper year and just managed to hold it the next year, the curve came down to zero. On the curve in Fig. 1 there was a logarithmic scale which made it look as though the increase in freight was flattening off, when in fact there were big increases in recent times. They should certainly be able to do something to alter the slope of those curves if they could design aircraft which were really suited to the purpose.

Four cents per ton mile had been mentioned as the current figure. He had encountered it as well in Australia, where the Managing Director of A.N.A. announced it to him as what they thought they would get in the very near future; and he remembered being greatly embarrassed because he had a brochure with him, which said that it was tenpence at the optimum range, which was about a shilling in Australia; Mr. Laight had already mentioned the very wide range over which this figure had varied.

N. E. Rowe (Blackburn and General Aircraft Ltd., *Fellow*): He had been most impressed by the enterprise of the organisation which had built this aeroplane and the way in which Mr. Keen had laid it bare before them—or part of it anyway. It brought an air of reality to discussions about this sort of aeroplane which as Mr. Haworth said, was certainly attractive to the British, with their great tradition as carriers of freight and cargo the world over. He had always felt that they would see cargo traffic in the air eventually, and he thought that this bit of enterprise might be extremely timely, because with the coming of the Common Market, which without doubt would eventually be an association of most of the countries in Europe, they might see a European freight organisation, which was badly needed. The idea of carrying freight on radial lines, which was the normal traffic method in Europe, had always seemed to him to be basically uneconomic because the return loads were likely to be poor, resulting in low load factors and unprofitable operations. But if one had freedom to carry freight between areas as was done in the United States, rather than from point to point, then they should get somewhere and the freighter might well find a very good market; then they might all feel grateful to those who had had the enterprise to go on with the project Mr. Keen had described.

The penalties he thought were very real in building an all-purpose freighter; one tended to lose the shapeliness as someone mentioned earlier. He thought it was necessary to have adequate access on the fore and aft line of the cabin; the sideways entry, if one were really thinking of cargo, *i.e.* large loads, and not freight, *i.e.* mainly small packages, was really ineffective. The air cargo vehicle should have a central entry which must expose the full cross-section of the hull for entry of the largest loads, but whether such an entry was needed at each end he was not at all sure.

He was struck by the reference to the size of the aeroplane, which was, he gathered, schemed round expected loads and densities. He would have guessed that the designer would build the best thing he could round four Darts, but apparently he used some other formula, although possibly Darts came into it pretty basically.

Would Mr. Keen give them a figure for what he had to pay for building it as a freighter, putting doors fore and aft, having the kind of layout that he had? He thought that it must be fairly high. If one took the product of ratio of payload to all-up weight, and payload which he suggested was a measure of transportation efficiency, the figure on his reckoning came out rather low and he put this down very largely to a rather low ratio of payload to all-up weight, probably due to the amount of extra structure which had been put in to provide all the facilities provided as a freighter. He agreed with Mr. Keen entirely that eventually they must not mix freight-dealing and passenger-carrying, and the idea of having the seats folded back to make room for the freight was a salesman's point rather that a real freight-carrying point, because one would then be carrying round a great deal of useless load and he did not think an operator would do that.

The amount of "fresh air" had been mentioned, *i.e.* apparently waste space. One would find a lot of "fresh air" in ordinary passenger-carrying aeroplanes; it was necessary and he did not think that that was much of an argument at all. One could not have a pencil body to accommodate only a certain average freight density; a reasonable variation in cargo density must be allowed for and he thought that although the hold was not filled on every occasion at full payload, this did not imply a criticism of body size.

Mr. Keen had, up to now cleverly avoided saying what the operating cost of this aeroplane would be. That was really where it would stand or fall. If Mr. Keen did not give the figure they would have to work it out for themselves!

F. R. Davies (Joseph Lucas (Gas Turbine Equipment) Ltd., *Chairman*): He had had some experience of flying freight in DC-3's during the war and some of the problems that they had to contend with were the lashing down of the load, which used to shift on take-off, and another was that the toilet was at the rear, which meant clambering over six or eight feet of goods. Would Mr. Keen consider having the toilets at the front in all future pure freight aircraft?

On short-haul routes if they were merely taking a load from A to B then c.g. problems were all right. It was all worked out before they took off. But if they were landing at a number of airfields and dropping a part of the load and picking up more load, then the question of loading for quick turn-round became important.

The car ferry at the moment was limited to cross-channel but he did not see why internal car ferries would not be a good thing to be boosted in the south, if people wanted to spend a motoring holiday, say in Scotland, it would save a considerable amount of time, because the new motorways were a long way off yet, and if one could fly to Scotland with one's car then one would have the maximum amount of time there.

Between Burma and Siam there were no roads so there might be a market for a freighter of this sort in that part of the world.

H. Templeton (Ministry of Supply, *Fellow*): *Contributed*: Mr. Keen had made a notable contribution to the somewhat vexed question of air freighting. He had made a commendable plea for getting down to business in the design of air freighters, for designing a cargo box that could fly rather than an aeroplane that happened to have space to store things. He had also presented some interesting information on the general question of air freight potential and the extent to which air freighting could, if properly catered for, take over a still greater proportion of the total freight market. He found of particular interest Mr. Keen's comparison of surface and air freighting in the particular case of watches being transported from Switzerland to Singapore. Detailed comparisons of this kind could be multiplied with advantage in assessing the potential capability of air freighting.

In relation to air transport the present scale of air freighting was of course not inconsiderable. His information was that excluding Russia and China the world total of freight ton-miles was now about 23 per cent that of passenger ton-miles, having been 30 per cent in 1951 before tourist passenger services were widely introduced. Since this scale of freighting had been achieved with aircraft that were in the main not designed for this specialist application, there was some reason to expect a significant increase if aircraft properly designed for the work became available. The scope for increase was shown by the fact that, in relation to all forms of freight transport in and out of the U.K. in 1957, air freighting provided only 2·9 per cent by value and 0·4 per cent by weight.

While the availability of suitable freighters was an important factor influencing possible expansion in air freighting, another important factor was undoubtedly the level of air freight rates. Studies had been made attempting to derive a relationship between the volume of air freight and its cost, and these studies generally concluded that cost was at present a holding factor and if substantially reduced would result in an enormous expansion of air freighting. It was therefore worth considering this question of cost a little.

It was obvious that the various items which contributed to direct operating costs would vary in relation to each other depending on the size and range of the aircraft, but over quite a wide range it remained a fact that two dominant items were the amortisation and maintenance costs. To reduce these costs therefore meant reducing first cost and providing the best possible maintenance characteristics—that was, a conscious effort must be made to make the vehicle as simple and reliable as possible, with low production costs.

Two other factors which affected the operating costs in a general way were the utilisation and the size. Greater utilisation meant lower cost per ton mile, and everything possible should therefore be done by manufacturer and operator to increase utilisation. Reliability exerted its influence here again, but it was also important to reduce turn-round and loading times by suitable design of the aircraft and loading system. Mr. Keen had rightly put the spotlight on this aspect in his paper. On the question of size, increasing capacity payload generally reduced cost per ton-mile, provided the capacity could be used. This immediately lead the manufacturer to the problem of estimating the maximum size the market would take, bearing in mind that the number of aircraft produced would also be reflected in production costs.

Desirable targets to aim at were thus, low first cost, ease of maintenance, quick loading facilities and large size. It was clear that in the Argosy a serious endeavour had been made to achieve the first three. As far as size was concerned it was fair to assume that the designer, on the basis of his extensive market research had provided what he considered to be the right answer.

R. D. Cullum (Technical Editor, "Engineering Materials and Design," *Associate*): *Contributed*: Although no longer directly connected with aircraft projects, he had read the paper with great interest, and agreed up to a point with Mr. Keen's conclusions.

He parted company on the suggestion that passengers should be carried until the business was on its feet. While admitting the trend of mixed cargo, using successive stages to obtain an objective often defeated the end. An "all out" freighter design was likely to be more economical in every respect, the reduced freight charge possible thereby (assuming I.A.T.A. consent!) would, he was certain, hasten the increase in air freighting.

A further point was whether the size of aircraft Mr. Keen had in mind was really the most economic size, bearing in mind the potential routes on the map. This in turn was tied up with bulk or packaged cargo. Surely the answer lay in the largest possible aircraft. Airport limitations were likely to restrict landplanes to 500,000 lb. A.U.W., but no such limitations existed for sea-based aircraft.

The advantages in sea-based freighters he had put forward in a lecture to the Christchurch Branch of the Society in February, when he was able to show that with an aircraft of the right size designed specifically for freight, a reduction of nearly 75 per cent could be made to the present direct operating costs.

MR. KEEN'S REPLY

B. P. Laight: Mr. Laight had agreed with him on so many of the points that he felt very gratified, but on the detailed points which Mr. Laight wished him to talk about it would be a little difficult in some cases to give him any specific answers here. The direct operating cost was a very difficult and dangerous parameter to use on its own and in any case it must be tied to a value of annual utilisation which might not be applicable. He had indicated on the diagrams how this utilisation could be varied so that he agreed the matter could be carried a little further and the variation in cost per ton mile on the utilisation worked out. Route studies were the only answer but the trouble was that much of the information used was confidential to the operator concerned.

The place of freight aircraft in underdeveloped territories, was of course more clear-cut than in areas with well established surface transport facilities. In Northern Canada a great deal of work was going on which could not have been done at all except for aircraft; they had used helicopters a great deal and they were very conscious of the advantages of using aeroplanes of all sorts. South America, too, he thought was an area of expanding economy in which aircraft would be used for freight purposes.

He agreed heartily with Mr. Laight that they would not get a long way just offering freight aircraft to the operators without taking into account that that was the whole freight transportation system. But it was very difficult to get all the operators to think alike. "Cargonising" was one of the obvious solutions but as he indicated in the paper, this had had a very lukewarm reception. The success of the Cook Strait operation seemed to give an unmistakably good impression yet other people were so slow in taking it up. His direct answer to Mr. Laight's query was that palletising should be as simple as possible,

and he thought that that was one of the reasons why some of the proposed transportation systems were not catching on. Designed as they were for side loading at great heights from the ground they were extremely costly and anything but universal. He would say that the essence of the transportation system must be simplicity. So far as the pallets were concerned, of the simple type shown in the paper, those had been taken up very vigorously in Birmingham by Fisher and Ludlow as a means of transporting goods on lorries. The Fairchild box idea would be all right for an old-fashioned aeroplane, which did not require pressurisation in the freight hold and on those grounds alone he was of the opinion that this conception was well behind them.

The penalties for passenger-carrying were numerous of course; there was no doubt about that and like Mr. Laight he would like to throw them all out of the "non-existent windows."

Mr. Cronbach: If he could just sum the whole thing up—why they had chosen an aircraft of this size—he thought they felt that this was the largest aircraft that the present freight market could employ economically, although admittedly on medium range routes.

They felt that the twin wheel undercarriage with tyre pressures of the order of 70 lb. p.s.i. would cover the large majority of airfields likely to be used, including grass and semi-prepared surfaces. There were ample provisions for providing a lower tyre pressure if anybody wanted to operate aircraft in under-developed territories, but this would incur a weight penalty and reduce the general appeal of the aircraft to the large majority of potential operators.

Mr. Cuss: He would refer Mr. Cuss's recommendation about Russia to the sales department; he did happen to know that they were trying to interest the Japanese at the moment and he feared that they were just as likely to copy them after buying one or two as well.

It was rather curious that Mr. Cuss should mention the Argosy being open at both ends because in one copy of the firm's House magazine, the Argosy was in fact depicted like this with a piece of red cloth on the rear end of the girders as well! (A.W. Affairs.)

He agreed about the speed of freight and that the freighter should stop once or twice going over the Atlantic; the aircraft under design at the moment would carry a useful payload all the way round the world.

J. O. N. Lawrence: He did not think the glider train would really come into civil operation from a safety point of view, but the freight density point which Mr. Lawrence made was a very valid one. He thought it showed the difficulty of deciding on the optimum size. He thought he should really draw attention to the statement which he made in the paper that so far all freighters had been designed to take military vehicles and therefore they were all pretty wide anyway.

N. E. Rowe: The estimated optimum operating cost per short-ton statute mile, based on 3,000 hours annual utilisation and using A.T.A. costing methods was 7d.

The question of efficiency was bound up with suitability. He thought Mr. Rowe was not really quite right in saying that their aeroplane was inefficient completely because of the parameter which Mr. Rowe had used, *i.e.* ratio of payload to all-up-weight. An earlier speaker mentioned working in out-back areas and in fact pin-pointed the question by referring to the tyre pressure. There were two ways in which their aeroplane was unglamorous, one was in the speed and that would pull the efficiency down if the conventional cost per ton-mile formula were used and the other one, which was inter-related, was that they had given it a pretty short take-off run. Compared with the Viscount, for instance, the wing area was one and a half times as big with consequent increase in structure weight. He would respectfully suggest, if one wanted to compare the two that, the efficiency factor of a particular design quite apart from the operational efficiency, must take account of the take-off distance. It was a fact that they felt the aeroplane would not be attractive to operators in semi-developed areas, for example in India, South America and even some of the more remote places in Australia, unless they had done something about the take-off distance.

The folding seat philosophy was a curious one he agreed. However, Independent Operators were making extensive use of folding seats. The alternative was to take the seat out when freight was carried. The inevitable would happen someday that all the passengers would be at one end of the route and all the seats at the other!

Mr. Davies: He could assure Mr. Davies that so far as the lashing down was concerned the Argosy had quite adequate arrangements and the crew toilet was in the front door.

He thought that Mr. Davies raised a useful point in talking about the c.g. position on intermediate stops, and that was one of the biggest cases for front and rear doors. There might be the case where one would have to completely unpack the aircraft and pack it up again with an awkward load, if one only had one door to enable one to manoeuvre it round.

So far as a car ferry was concerned, he would be less than honest if he did not tell Mr. Davies that he was really going to be a bit disappointed. This car ferry operation to be economic depended on the shortness of the route. It was quite uneconomical with present and projected car ferry aircraft to travel from the South of England to the North of Scotland by air with one's car.

R. D. Cullum: He must, of course, agree with Mr. Cullum's comments, but at the same time point out that they were really not trying to win a point in a debate but persuade the operators to do something about it. In this connection, it was their conviction that operators were not yet prepared to embark on the scale of operations which the undoubtedly more economical large aircraft would be able to undertake. In this connection, he really believed that it was immaterial as to whether the aircraft were land-based or water-based.

The President (Sir Arnold Hall): He was sure that they would agree that a lecture such as this, simple and straightforward, delivered clearly and provoking such an excellent discussion was well worth while. He was very glad to be present as President of the Society and also because he was a colleague of Mr. Keen's. He had seen the wholehearted enthusiasm that Mr. Keen had brought to his study and design of this aeroplane and the magnificent team work of the people behind him, whom he had largely chosen and whom he lead so well. He thanked Mr. Keen both for all he had done and for his lecture.

The Economy of Structures*

by

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1. Introduction

To anyone who knew Barnwell, however little, it is a great honour and pleasure to be invited to give this lecture as a tribute to his memory. I was too young and too remote to have known him well, but he was the first leading aeroplane designer that I ever met. Some older members of our Society will recall the aeroplane known as the Bristol Bagshot: and a few will remember that in its early flights it was found to suffer from an unexpected, and at that time new, form of control trouble. This occurred shortly after I had started work in the old Airworthiness Department at Farnborough, and the investigation of this new trouble, later to become known as "Reversal of Aileron Control," was put upon the new recruit. As a result I came to know Russell, as lively a young man at Bristol then as now, and was taken by him to see Barnwell. I was struck then, as afterwards, that here was a designer of insight and great kindliness who had learnt to combine engineering with the humanities to an unusual degree; and, as I realised afterwards, he had also learnt how to encourage and get the best out of the young men around him. And so I, like so many others, came to admire him.

When, therefore, I was asked to give this lecture, I found myself more than usually anxious to choose a subject that was both after Barnwell's own heart and at the same time even partially within my compass. Thinking back over Barnwell's work, and indeed over subsequent developments due to those who grew up under him, I came upon the branch of the science and art of structures represented by my title. However inadequate my treatment of the subject in this lecture, I am sure, as I hope to be able to show even to those who never knew Barnwell, that its matter was of lively interest to him. By tracing some aspects of the history of the subject, I hope too to show something of the part that Barnwell himself took in its advancement.

2. Nineteenth Century Structures

By the last quarter of the nineteenth century the use of wrought iron and mild steel in building and bridge structures had become so common that the centre of interest among some leading designers shifted from a concentration on how to do a given structural job to an interest in being able to do it more efficiently. At such a stage in a given line of structural development, as will be seen again later, there are always some engineers who become interested in the problem of choosing the most economical design for a given structural job, several ways being practicable. The history of the subject reveals a number of such waves of interest; indeed it is in this respect like many other branches of English history, which to readers of *1066 and All That* is clearly constituted of "waves," starting with the Angles, Saxons and Jutes!

In the late nineteenth century, this interest became largely concentrated upon two design problems, one associated with columns or struts and the other with lattice girders.

The understanding of the behaviour of struts in general engineering grew up first around the cast iron columns so commonly and effectively used throughout the nineteenth century, and then became related to wrought iron and mild steel struts through an interest in the use of these materials in frameworks. It was thus only as such frameworks became more ambitious in size and load carrying capacity in the last quarter of the century that the design problems of heavy struts in these ductile materials came to the fore. It was natural that several alternative approaches were attempted and, in particular, comparisons were made between open latticed struts, built up of angles and channels, and closed tubular struts, the latter derived from such early and skilled advocates as Robert Stephenson and I. K. Brunel. By the end of the century, Sir John Fowler and Sir Benjamin Baker had used both types in the Forth Bridge and clearly knew a lot about their relative merits for various conditions.

This late nineteenth century work is epitomised by Professor Claxton Fiddler's chapters on struts in his *Practical Treatise on Bridge Construction*[1], published in 1887. Relating directly to our subject, he has an article therein on the practical weight of struts touching on, as he says, how "the comparative economy of different forms varies in different situations." From this it is clear that he realised with—to those of us who first approached the problem between the World Wars—quite surprising clarity that the most economical (in terms of weight) form of strut for given conditions depended primarily on the axial load, P, it was designed to carry and the length, L, over which this load was to be transmitted. Fig. 1 is based on his own diagrams and clearly shows his appreciation of the fact that different sections are appropriate to different ranges of strut load and length. The curves shown make no reference to tubular struts, but of the merits of these for cases of very heavily loaded long struts his text elsewhere indicates that he was well aware. Our generation is thus by no means the first to appreciate that, for a given structural purpose, different types of construction are best suited to different ranges of loading and dimensions; nor the first to draw intersecting curves to illustrate this fact. I am particularly glad to draw attention to this here in Bristol, because my oldest

*The Fifth Barnwell Memorial Lecture given to the Bristol Branch of the Royal Aeronautical Society on 17th March 1958.

lecturer, Col. W. N. Elgood, who has recently retired, was a student of Claxton Fiddler's.

A somewhat similar development grew up around the lattice girders of the same period. It followed a time of great inventiveness and experimentation in girder forms; Warren girders, single and double, and Pratt trusses, single and double too, came in quick succession with a host of others now hardly remembered. And in the last quarter of the century, engineers surveying, for example, their parallel boom girder problems, came naturally to do so in terms of economy.

There seems first to have been an interest in the best angles of inclination for the web members in such trusses. Thus Stoney, in his *Theory of Strains*[2] published in 1873, devotes a whole chapter to the Angle of Economy. Studying first the web members of a generalised form of Warren truss that he calls the "isoceles girder," he deduces from an approximate equation for the weight of the web members that the angle θ they subtend to the vertical should, for economy, be 45° rather than the 30° of the common Warren girder. A similar investigation into the inclination of the diagonals in a Pratt truss shows that these are best placed at 55° to the vertical—a somewhat surprising result in relation to modern practice. For these particular configurations he produces a table showing the relative weights of the three kinds of girder, thus:

Isoceles girder ($\theta = 45°$)	1·000
Warren girder ($\theta = 30°$)	1·155
Pratt truss ($\theta = 55°$)	1·415

Claxton Fiddler, looking at the same problem in a less mathematical but more philosophical way, came to the conclusion that for all such parallel boom girders the minimum web weight was achieved when the weight of the struts was exactly equal to the weight of the ties. This he and other leading engineers of his generation appear to have regarded as a basic theorem in truss anatomy. But Claxton Fiddler makes it quite clear that the optimum so achieved is a flat one and not to be adhered to with rigour to the disadvantage of other features of a bridge design, such as the spacing of cross girders for a bridge deck.

Extensive experience had meanwhile gradually built up a practical knowledge of the relative economy of different types of truss under different situations. Thus in 1872, in his book on *Works in Iron*[3], E. Mathison was able to place a series of truss forms in order of merit, as in Fig. 2, for wrought iron bridges of 100 to 200 ft. span. This order was given, of course, for a typical system of loading such as uniformly distributed loading.

A more important aspect of such truss design, and one that has proved of more lasting interest, is the proportion of depth to span. Early wrought iron girders in the nineteenth century were usually shallow, with depths about 1/16 of their spans, and it was largely as a result of economy studies that deeper girders were later adopted. Claxton Fiddler decided that a depth of 1/10 to 1/8 of the span was likely to be most economical, but noted—with a strangely modern touch—that American girders seemed to be lighter than ours, "perhaps because they used still deeper trusses, but mostly because of better detail design." By the first decade of this century there was general agreement that a depth of 1/6 of the span was about the optimum for low structure weight, and that the optimum concerned was a flat one, so that depths of 1/5 to 1/7 of the span showed little change of girder weight.

There was a third problem of this last part of the nineteenth century that deserves passing reference. Engineers of that time were moving towards the end of a period of railway viaducts and came, therefore, to consider the economic span between individual piers in such structures. In many cases, piers and girders were of different materials—masonry and wrought iron, for example—and so any discussion of economy in such a case had to be conducted in terms of costs, or at least relative costs. By writing an equation for the total cost in terms of pier and girder costs, and their variation (mainly that of the girder) with the span adopted, differentiation leads to a best span, L, for minimum total cost.

Work of this nature was also taken up in America, and is well recorded in a book by Merriman and

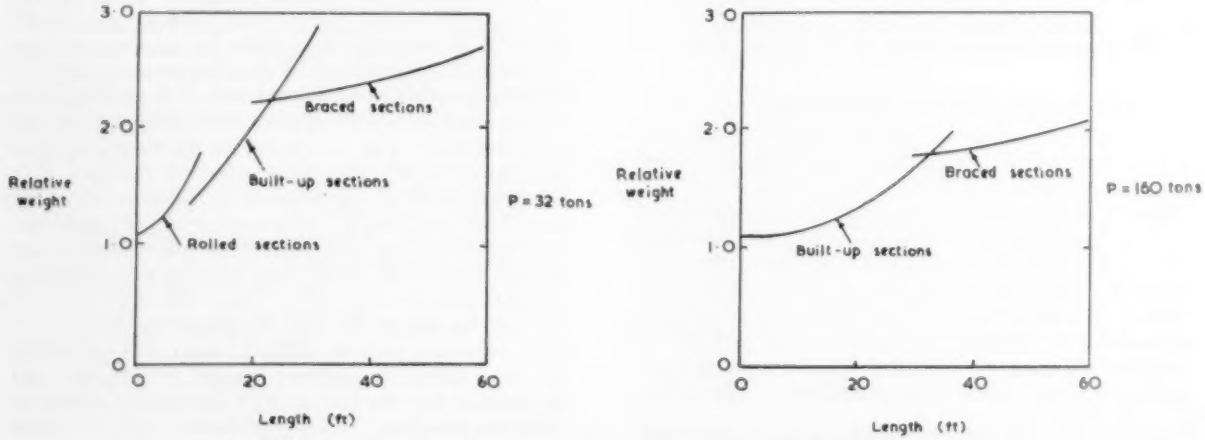

FIGURE 1. Variation of column weight with end load (P) and length. (Wrought iron.)

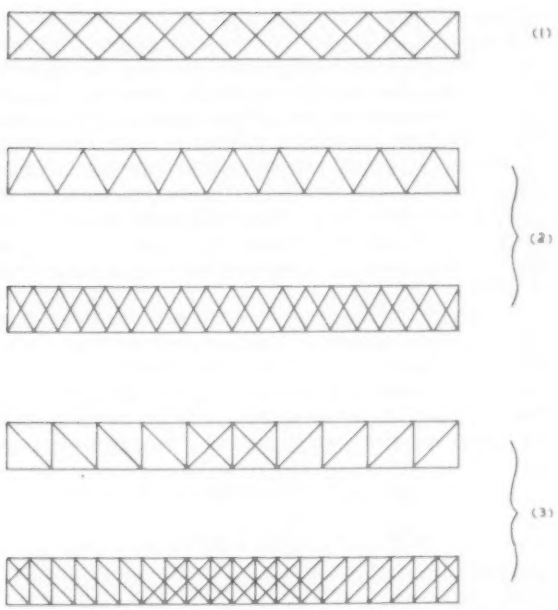

FIGURE 2. Order of merit of lattice girders. (Wrought iron.)

Jacoby[4], published in 1917. They give for the economic span

$$L = \sqrt{\frac{C}{pb}},$$

where C = cost per pier (taken as constant for the range of span considered)
b = constant governing variation of weight of girders with span
p = cost of girder material per unit weight.

For a steel girder on a variety of piers, this expression gives the results shown in Fig. 3. Costs are there expressed in terms of the pound sterling. The curve illustrates the slow increase of economic span with pier cost and how moderate the economic spans are.

3. Early Aeronautical Structures

Enough has been said of the wave of work in the late nineteenth century on the economics of civil engineering structures. Let us turn now to the development of similar work on aeronautical structures in the first half of this century. Until the First World War aircraft structures, whether of aeroplanes or airships, were in a tentative and exploratory stage, and so it was not until the war was well advanced that appreciable work in the economy field developed.

Just as I referred to a book by Claxton Fiddler as epitomising the work in the late nineteenth century, let me now refer—again with every appropriateness in Bristol—to Pippard and Pritchard's book, published in 1919, on aeroplane structures[5]. The strut problem again looms large; Southwell's adaptation of the Perry formula for use with tubular struts of commercial straightness and accuracy, and Robertson's modification

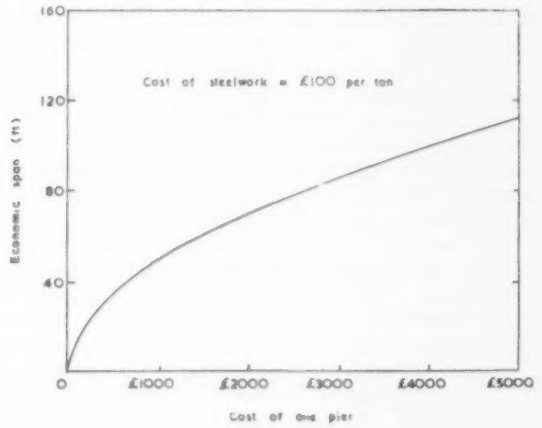

FIGURE 3. Economic spans for steel viaducts.

of the same formula for more general use, both belong to this period and grew out of the needs for biplane design. But there are clear signs too of economy debates. Solid spruce struts were commonly used for interplane struts and could clearly be tapered with advantage; how could their strength then be estimated and what savings of weight be thus effected? Out of this work grew the Barling and Webb tapered strut showing a weight saving of up to 13 per cent, and the Arthur Berry elliptically tapered strut, names well known to the older generation among us and personally known to Barnwell. Of more immediate interest to us, however, is a section in the book on the "most economical straight tapered strut." Here an analysis is given showing that, for a maximum critical load for a given volume of material, a solid strut with ball ends should be tapered so that, for example, its diameter at the ends should be 0·434 times that at its centre. By so shaping the strut a saving, compared with a uniform section strut, of 18 per cent is effected.

In the same book brief mention is made of the aeroplane parallel to our earlier truss problem. Fuselages were at that time constructed of four plane trusses arranged to form the four sides of a rectangular section tube, the outside of which was covered by fabric. In such a structure a decision has to be made as to the bay spacing, and it is evident that this question had received some attention with the result, not unexpected from the previous civil engineering work, that "the question of bay spacing is one largely of taste. It will be found, if a number of different spacings are adopted, and the weights of the resultant structures calculated, that there is very little to be saved by the use of one rather than the other."

We have come now to the beginning of Barnwell's most productive period, and to the real text for this paper. Barnwell seldom wrote in the scientific or technical press, but in 1919, at the same time as Pippard and Pritchard's book appeared, he wrote a paper for the Royal Aeronautical Society modestly entitled "Some Points in Aeroplane Design"[6]. The paper is introduced in the same spirit, "It is probable that what I have done has been done already by most people who have been

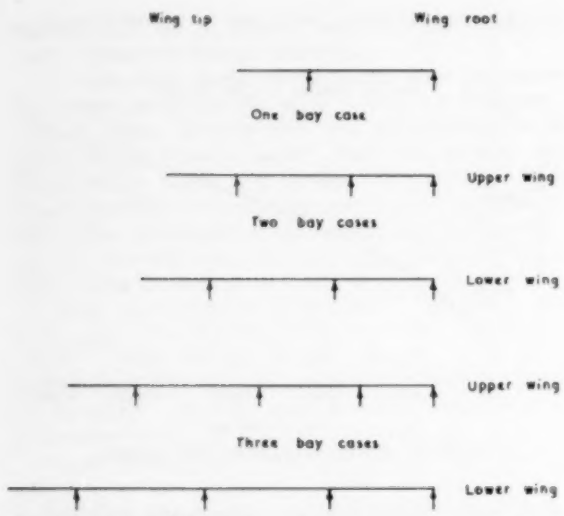

FIGURE 4. Economic positions for support points. (Biplane wings.)

engaged on designing work for the last few years, and probably done more fully and accurately. But it has entailed quite a fair amount of work, and the results have been of some interest and value to myself so I hope that they may prove the same to others."

The first structural problem he touches upon is one of economy and although he is of course referring to biplanes, one that is still of interest today. "I have attempted next," he says, "an investigation into the optimum position for the main spars of an aerofoil. I have assumed the usual practice of two spars only, though there is an interesting field for further investigation as to whether it might not be of advantage to use a greater number. For a very highly loaded aerofoil it might prove economical to employ more than two spars instead of increasing the number of supports." Using a tabular system of marshalling his data and calculations, and referring all the time to spruce spars of approximately I-section, he comes to the conclusion that the lightest configuration is that when the front spar is at 0·08 chord and the rear one at 0·42 chord, both much ahead of the then conventional positions of 0·12 and 0·62. He proceeds, however, to note "But the curves are very flat and bunched together for all cases when the rear spar is ahead of 0·66 and the front spar behind 0·08." For the conventional positions the weight was only 6 per cent greater than the minimum.

He realised, of course, that this analysis was only a start upon the problem, for clearly the spar structure weight will depend also upon the spacing of the points of support, provided by the biplane truss, along the main spars. We are in fact here discussing the biplane equivalent of the viaduct problem already touched upon. Realising the complexity of the whole problem, which clearly involves the truss system as well as the spars, Barnwell tackles next the simple problem of support spacing for spars of uniform section along their length. Concentrating upon the spars to one side of the "centre section" at the fuselage, he arrives at the economic support spacings for a variety of simple and multi-bay biplanes. In doing this, it should be pointed out that he allowed not only for the bending actions due directly to the wing loading, but also for the effects of the end loads in the spars as part of the biplane truss system. Fig. 4 illustrates his results, all drawn to the same scale.

So far structural economy has been discussed in terms of first cost without reference to economy of performance thereafter. Barnwell's next inquiry is an intriguing one straight into this virgin field. Turning to the interplane struts, and knowing the work, for example, of Barling and Webb, he poses the problem—"if I take a Barling and Webb strut as an efficient one of its kind, and discuss its weight in terms of the end load P and length L, can I not link this discussion with the air resistance offered by the strut?" His immediate step at this stage gets no farther than a statement of the weights and drags involved, neatly expressed for subsequent use as

$$\text{weight of strut} = W = 0{\cdot}0000286\, L^2 \sqrt{P},$$

$$\text{resistance} = R = \frac{64}{10^5}\, v^2 \sqrt{(LW)}.$$

Here W and R are in pounds weight, L in inches and v in ft./sec.

He gets no farther with this structural-cum-aerodynamic isolated strut problem, but, after accumulating comparable data for the other components of a biplane, attempts the overall problem of relating total structure weight and performance. By studying a number of biplane layouts, he comes to the conclusion "it would appear that for manoeuvrability certainly, and speed probably, the shortish span machine has the advantage, whilst for climb, weight lifting and range, the machine of high aspect ratio is distinctly superior." Barnwell has here given an interesting glimpse of an early example of our many structural-cum-aerodynamic problems in the field of economy.

4. Figures of Merit

With the introduction into aeroplane structures of metal construction generally, two new fields of work affecting structural efficiency developed. The first, in the 20's, concerned the design of metal spars for biplanes, and the second the use of plating in all parts of the monoplanes of the 30's. The first revolved round the use of high tensile steel strip rolled and drawn into a variety of cross-sectional shapes to form components of special steel spar sections. These sections, designed primarily to enable thin steel to withstand compression stresses up to 60 or 70 tons/in.^{2}, the proof stress of the material, without premature local buckling, showed great ingenuity in the use of transverse curvature for this purpose and were largely very successful. Different types became known by the names of the firms specialising in their development and use, and the Bristol spar of the time, developed under Barnwell's guidance, was as well known as any.

So far as I am aware, the use of structures built up of more or less flat plates came first into aeronautics on a generous scale in the larger airships of the 1920's. Attempts to provide generous passenger accommodation in the Graf Zeppelin, and later in English and American

airships, brought into being fairly long span plate and box girders with flanges and webs of much thinner proportions than was customary in the mild steel structures of civil engineering. In Zeppelin practice, for such girders with webs up to some 6 in. deep, the web plates were often both " lightened " and " stiffened " by having flanged lightening holes formed in them. But as the need for deeper webs arose, the alternatives of deep plate webs (however stiffened) and of tubular web members arranged truss-wise clearly presented themselves; for a given shear force and given depth of web, which was the more efficient?

At about the same time Wagner[7] found that for some spars, particularly where the shear forces were small, tension-field webs could be devised and used with economy. In such webs, it was possible to allow the thin plate to buckle in shear between fairly closely spaced " stiffeners " to form an effective sheet of tension diagonals, the necessary compression being carried by the " stiffeners." The latter, usually arranged vertically, thus acted primarily as the compression components of a web truss system rather than as web plate stiffeners.

These developments led Wagner to look more closely than had been done before, at the conditions which made one or other of these three types of web the most efficient. Just as in the strut problem the end load P and the length L were isolated as the governing factors, so in this web problem Wagner concentrated on the shear force F and the web depth h available for the structure to carry it. As a result he was easily able to show—although when first he did so its simplicity came as a surprise to other workers in the field—that the value of F/h^2 was a direct pointer to the type of web that would be most efficient for a given application. With this in mind it is easy to study a few practical examples and discover that the heavy plate webs of short span civil engineering bridges operate with F/h^2 values of the order of 100 lb./in.^{2}, whereas the webs of large deep truss bridges have values as low as 2 lb./in.^{2} Shanley[5] has since produced diagrams of the type illustrated in Fig. 5, whence the efficiency of different types of web can be deduced for different values of F/h^2.

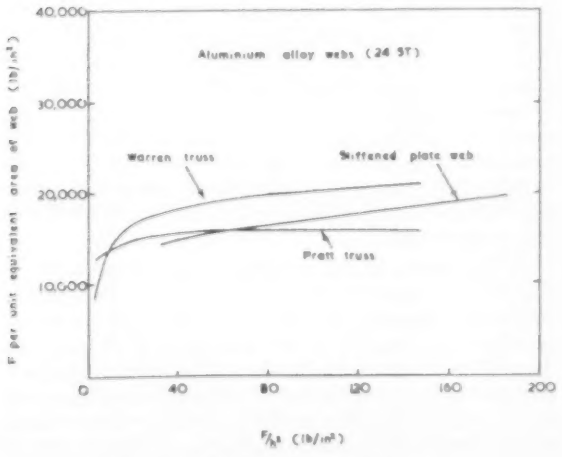

FIGURE 5. Efficiencies of shear webs.

This use of a parameter like F/h^2 was not entirely new. Barnwell, in the paper previously mentioned, had already referred to numbers measuring the strength of a structure for a given weight and purpose as " figures of merit," and the same term had been in common use among airship designers for the ratio of the strength to the weight of a strut for a given length. Already therefore, strut parameters such as P/L and P/L^2 were in tentative use, and Wagner's F/h^2 was a coefficient or index of the same kind. Thus clearly to state a structural problem in terms that could act as a pointer to the ranges of efficiency for given types of construction, however, was a great step forward, from which we are still benefiting. In the hands of Shanley and Gerard[9], in America, the beam problem has been furthered, in its bending aspect, by using the coefficient M/L^3 in addition to the shear coefficient F/h^2; and they have successfully approached more complicated plate and shell problems in the same manner.

Of greatest general interest to aeronautical engineers are the advances in this field of coefficients for the plate structures of modern aeroplane wings. In this country, research and development work has in large measure been due to Bristol designers in collaboration with H. L. Cox. This phase of the work brings us to recent post-war years, during which such parameters have been formally blessed with the name of " structure loading coefficients " in England and of " structural indexes " in America. That Bristol aeroplane designers, led by A. E. Russell, should still be pioneers in this field is not a surprise. The Barnwell interest in structure efficiency has proved a strong and growing plant, of which a typical fruit is the lecture given by A. E. Russell in the United States in 1949 on " Aircraft materials from the designer's point of view."[10]

Having realised that P/L^2 and F/h^2 were the best forms of structure loading coefficient for struts and shear webs respectively, these workers considered the stiffening skins of aeroplane wings and fuselages on similar lines. Is it best to use, for a given bending moment on a wing section of given depth, a thin skin with heavy reinforcement by stringers, or a thick skin with little such reinforcement? And for a given skin thickness, are closely spaced Z-section stringers better than more widely spaced top hat stringers? These, and other such questions, it was realised, can best be examined in relation to a structure loading coefficient for wing skins. Now the compression skin of a wing is like a wide strut of plating stiffened at more or less regular intervals by stringers. The loading on it can best be expressed by p, the compression load carried per inch of its width. For many cases this strut has to span between supports, the wing ribs, at a pitch L which differs little from one wing design to another; thus p, itself, is for many purposes a sufficient structure loading coefficient without specific reference to rib spacing; and more generally p/L is appropriate. We thus find Russell in his U.S.A. Lecture presenting the relative merits of different forms of skin structure, as in Fig. 6, in terms of p/L, the compression load per inch of skin width, divided by the rib pitch L.

This work, which almost coincided in time with similar independent work in America, came as

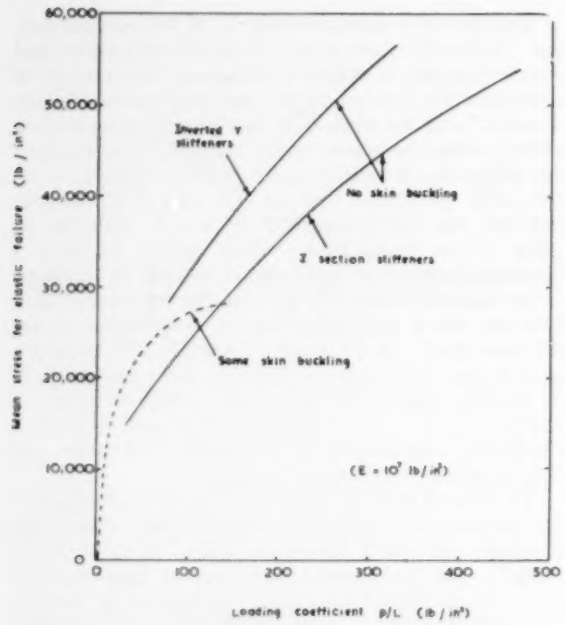

FIGURE 6. Strength of stiffened plating. (Aluminium alloy.)

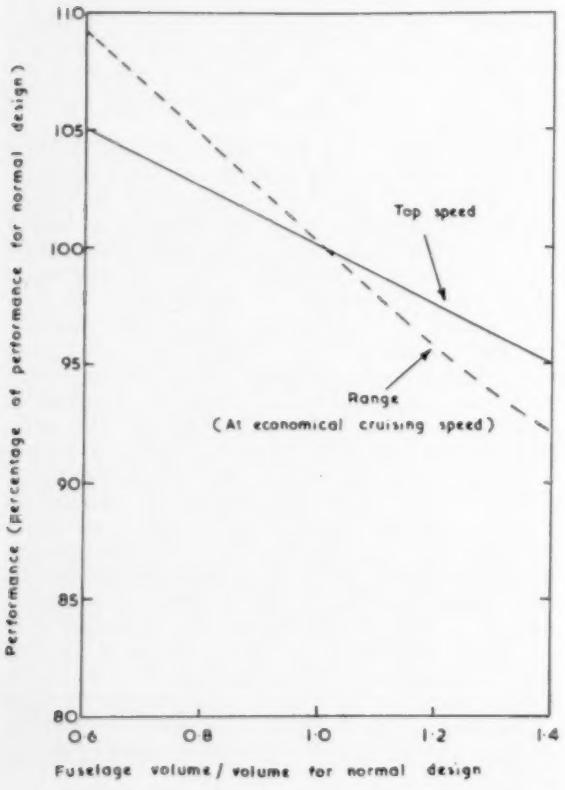

FIGURE 7. Effects (alternative) of fuselage size on performance.

refreshingly to wing structure designers as the earlier work of Wagner did to shear web designers, and found its first major application in the design of the wing structure of the Brabazon. At last, it seemed, a rational procedure was available for the choice of wing structure forms. But the end of this particular trail is yet to seek, if end there be; the loading coefficient approach only whets the appetite for a more direct method of choosing the best structure for a given job. For a prescribed set of external loads, may there not be an ideal, if not unique, structural arrangement? And, if so, can it not be determined by some logical process? All sorts of difficulties beset the path of those, such as H. L. Cox[11], who pursue this ideal. Structures, for example, are normally designed to carry not one, but several sets of loads; and they usually have to fit within a prescribed space.

5. Economy and Performance

While these developments in the art of detailed structural design were taking place, a new attack on the wider design problems of structures-cum-performance was made. In the early part of the Second World War, when several designs of aeroplane to the same specification were not only designed and built but also put into production and service, it appeared that a chance of comparing their structural merits on a wider basis had become possible. Lord Tedder was Director of Technical Development at the time and gave authority for the author to form a small section at Farnborough to try to advance the matter. Two aspects of performance seemed of special interest at the time—aerodynamic and production, the former in terms of speed or range, and the latter in terms of man-hours for construction. For the latter a link needed to be forged —none such existed before—between Farnborough and the costing side of the then Ministry of Aircraft Production. Lord Tedder was able to initiate a contact of this sort, but the natural lack of design understanding among costing staff and the pressure of events made this particular aspect of the work abortive.

The structural-cum-aerodynamic part of the work, however, made some real progress, although now clearly dated by the design circumstances of the time. R. & M. 2377 on "The Structural and Aerodynamic Effects of Wing Thickness and Fuselage Size Variation"[12] represents the first fruits of the group of staff concerned. It relates, naturally enough, to bomber structures of the Lancaster period, and its conclusions on wing and fuselage design, arrived at in 1940, seem less than wise in relation to the much higher speed designs of today. But its spirit is extraordinarily modern; an introductory paragraph states:—

"The merits of the structure of an aircraft can be judged in a number of ways. A simple and purely structural approach would be to regard the external geometry and loading of the aircraft, and the size and disposition of its internal loads, such as bombs and fuel, as fixed, and then measure the efficiency of the structure by its weight. But this would set unduly narrow limits to the structural efficiency problem. A better aircraft might result from changes of external geometry and a

re-arrangement of internal loading, alterations that would introduce aerodynamic as well as structural changes. Thus, for example, the choice of wing thickness depends partly on a weighing of structure weight against aerodynamic performance and partly on more general load stowage considerations. It is in such terms that wing thickness and fuselage size are discussed in this report.

"Any attempt thus to assess structural-cum-aerodynamic efficiency and to discuss structural arrangement is to move from the engineering science of strength and stiffness towards the art of aircraft design. This at once raises difficulties that are in themselves an indication of the importance of the step."

Here is the general problem sensed by Barnwell restated in terms that are still relevant today. Fig. 7 illustrates the approach to the fuselage size problem.

The work of that wartime section treated a number of then current design problems in this way, but with the end of the Second World War its staff became dispersed and the rapid changes in design conditions since then have made it unlikely, even if a similar section could have been refounded, that much useful work of a general character could emerge.

6. Modern General Engineering Structures

Work on the efficiency of structures has, since the last war, been prosecuted with as much energy in general structural engineering fields as in aeronautics. This has been largely engendered, directly or indirectly, by the post-war need for economy in the use of steel. Such work most naturally arises wherever a given steel structure or structural unit is required in large numbers, so that any saving of steel in the standard design is greatly multiplied. The braced steel towers used for electric transmission cables are of this kind and are a good modern example of design on an ultimate strength basis, rather than on a purely elastic analysis. Samples of proposed designs for such towers have been subjected to strength tests to destruction, and as a result their design has been refined—initially by trial and error and more recently by the development of theories to predict the ultimate strength of such frames—to save a considerable proportion of the steel required for a conventional design. Such tests were conducted in the U.S.A. as early as 1910, and in some cases result in as much as a 30 per cent saving of steel. The standard towers used in current electrification schemes in this country have been similarly designed and tested.

TABLE I

COMPARATIVE DATA FOR SINGLE-STOREY SHED CONSTRUCTION

Type of construction	*Relative steel weight*	*Relative total cost (1951)*
Tubular steel	2·6	2·3
Cold-rolled steel	2·9	2·6
Conventional hot-rolled steel	4·7	2·7
Reinforced concrete	1·2	3·3

Values based on designs for three-bay shed, each 40 ft. wide and 215 ft. long.

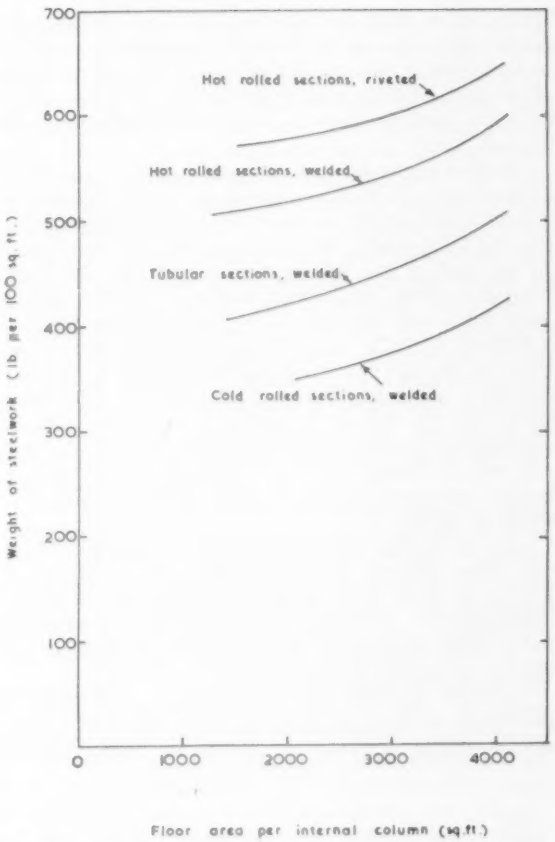

FIGURE 8. Weight of steelwork in industrial sheds. (Steelwork comprises roofing structure and columns.)

Another standard situation occurs in the construction of steel framed industrial buildings of only one storey. Here the roof loads, apart from the weight of the structure itself, are much the same in most English structures, and the aim is simply to provide, at a given height, a covering over a large floor area without too many columns. Approached in this way, one can study the amount of steel required per unit of floor area covered by a variety of column and roof arrangements. A paper[13] on the subject, written in 1953, includes graphs upon which Fig. 8 is based, and shows how the weight of steel required per 100 sq. ft. of floor covered varies with the column spacing and with the detailed type of construction. The curves given indicate the structural merits not only of modern tubular and cold-rolled steel strip designs but also of the old-fashioned adoption of closely spaced columns. The natural spacing of the trees in a beech forest seems to be an efficient one for covering, as well as carpeting, the ground! On the question of the relative merits of different forms of roof construction, another part of the same paper gives the table here shown as Table I. In this the weight of steel required for a given shed structure is transformed, in terms of the costs in 1951, into relative costs, thereby making allowance for the variations in fabrication costs involved. The resulting

figures show how real is the difficulty of reducing substantially the cost of such shed buildings. It is to be remembered also that all this work is based on code of practice methods of analysis and not on tests, which for such problems have hitherto proved impracticable in most cases.

A more recent essay of the same kind has been made in the design of flat floors composed of steel plates on a grillage of steel beams, as in the case of ship's decks. For the flight decks of aircraft carriers the main load on any part of the deck is the concentrated one of an aeroplane wheel. Since these loads have to be withstood many times with little deflection, Clarkson, in a paper[14] published in 1955, has analysed this problem on an elastic basis, how to space the grillage beams for greater economy. For any rectangular plan of supporting boundary, the lightest arrangement tends to coincide with that giving equal peak stresses in the two intersecting sets of beams, but the calculations required are lengthy ones and can only be reduced by resorting to a series of graphs.

The foregoing general engineering examples have only been outlined in broad terms, and it will be of interest to look in more detail at one or two recent investigations. Both relate to the design of a structure for a given ultimate load, irrespective (in aim) of its elastic behaviour at lower loads.

Largely at Cambridge and at Brown University, a great deal of work has been done on the development of the plastic method of design for steel building

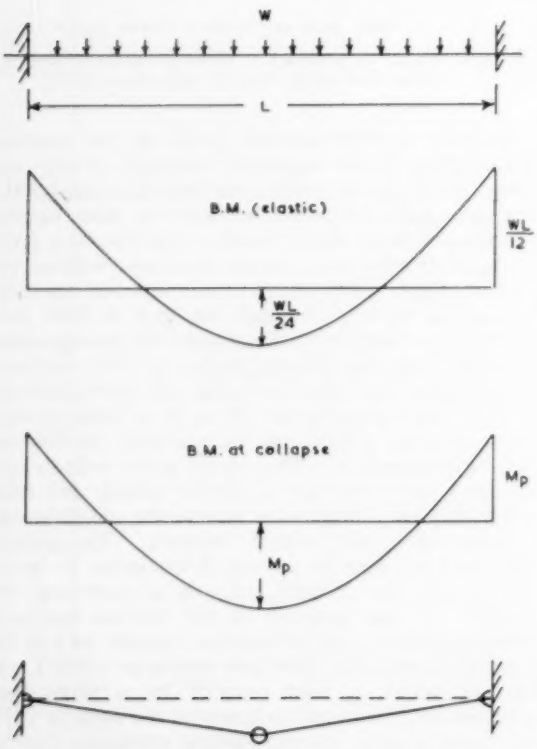

FIGURE 9. Collapse mechanism for fixed beam.

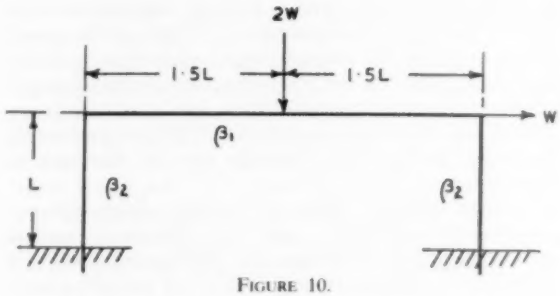

FIGURE 10.

structures. This has now reached a stage at which numerous applications are arising, and some of the exponents of the method have naturally turned to the study of its effects on the economy of structures. In 1952, Horne[15] examined by this method the most economical shape required of a fixed ended beam under uniform loading. Fig. 9 illustrates the plastic hinge mechanism by which a uniform fixed ended beam is taken to fail, and Horne aims to produce a beam such that the lack of economy associated with the local hinges in that case is obviated by causing plastic failure at every section simultaneously. If continuous variation of the beam section is possible and shear is neglected, a 35 per cent to 50 per cent saving in weight (compared with the uniform beam) is possible; but allowance for shear reduces these savings. The most economical way of reinforcing a uniform beam in practice under these conditions is to attach cover plates to its flanges at each end for a length of about $\frac{1}{8}$th of the span; in such a case, savings of 14 per cent to 22 per cent can be achieved in place of the ideal figures of 35 per cent to 50 per cent quoted.

With more complex structures than the beam just discussed, treatment of the economy problem has naturally been largely confined to assemblies, such as portals and building frames, of individually uniform members. Much of this work has been done by Foulkes[16] and Heyman[17] at Cambridge and for such frames has led to four quite general theorems from which designs for minimum weight can be deduced in any given case, under given loading conditions. Thus for the portal frame of Fig. 10 the design problem is to determine, in terms of the moment WL, the best strengths β_1 and β_2 for the beam and columns corresponding to collapse under the loads shown. In the plastic design method, these strengths are expressed by the bending moment necessary to cause fully plastic bending of the member concerned. An analysis of the frame illustrated shows that in that case a structure designed to collapse under the given loading should for economy have $\beta_1=\beta_2=\frac{3}{4}WL$. A more complicated example, in which the use of the theorems mentioned become of more obvious value, is illustrated by Fig. 11. In this case, a structure of minimum weight is achieved by adopting $\beta_1=17{\cdot}3$ tons ft. and $\beta_2=8{\cdot}0$ tons ft.

In a less advanced, but nevertheless related area, I and some of my colleagues at Bristol have been interested over the past few years: this is the prediction of the ultimate strength of plane braced frames, such as

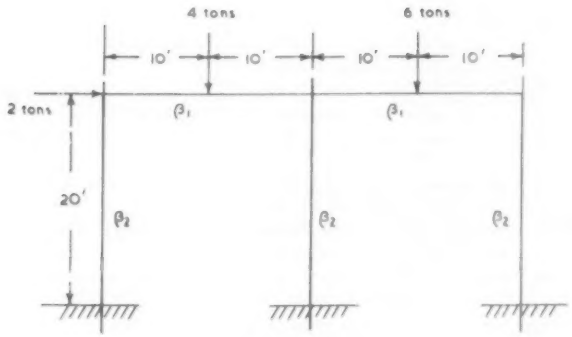

FIGURE 11.

N or Pratt trusses, with fixed joints, and thence the economy of such frames. In this work a number of trusses have been tested to destruction to the same specification as regards size and load, but of different detail design and material, and we have tried to deduce the mechanisms of breakdown of elasticity and of collapse in each case. It is too early to generalise on our results but a few broad qualitative points have emerged. Thus it is already clear that plane N trusses of ordinary proportions, whether in steel or aluminium alloy, unless stabilised laterally at nearly every joint, fail by general or local lateral instability. It also appears, as the history of the subject might be expected to have occasioned, that codes of practice tend to "play for safety" in their strut design clauses and so lead to plane frames liable to yield first (if kept plane) in one of its web tension members rather than in a strut. Following a test to destruction, partly because of this tendency to tension failures, it is not difficult to modify the original design, even when quite sophisticated, to increase considerably its strength for little increase in weight.

This last point comes full circle back to a point only too well known in aeronautics, although often too difficult, or realised too late, to take full advantage of. The somewhat premature collapse of the wing test specimen for the Brabazon was an excellent example of this point.

I have elaborated these examples because they illustrate, in other than aeronautical fields, the considerable efforts now being made to learn how to predict the ultimate strengths of structures and then to use this knowledge for their more economical design.

7. Economy and Safety

This survey of the economy of structures has been wide but by no means complete. It has been shown how economy investigations have been made for structures of many kinds and what considerable and fundamental contributions have been made by aeronautics. But one such contribution of major importance has been omitted to which reference must be made.

No concept of the economy of a structure is complete without a close inquiry into the purpose of a structure; and most structures have a purpose involving the carrying of a load or loads for a period of time. In some cases, as with a road bridge over the Thames, the carrying of loads with almost complete safety for perhaps a hundred years before replacement is required; in others such as a telephone pole, the carrying of loads with occasional collapse in storms, and replacement then or every 10 to 20 years may be the aim. Thus in most structures we are concerned not with complete safety for an infinite time, but with structures with an acceptable degree of risk of collapse and an acceptable life. And an acceptable life involves in many cases an acceptable repair and replacement cost so that a succession of similar structures can be kept in being so long as the need they meet exists. This overall economy problem, involving first cost, the probability of collapse and the cost of replacement was first studied in the civil engineering world, but its most unconventional element, the probability of collapse, was earlier introduced in the aeronautical field and has grown to represent not only collapse under static loads but also under fatigue conditions.

I endeavoured to outline the developments leading to this overall picture in a paper to the Society in 1955, given at Preston[18]. In a more recent paper[19] for the Institution of Structural Engineers I pointed more definitely to the relation between structural efficiency and structural safety. In the static case, for example, we decide upon a load factor involving a given risk of collapse in order to save the structure weight that would be necessary to ensure a much smaller risk. In many structures under their appropriate loading conditions, for example, a 10 per cent increase in specified load factor would result in a ten to one reduction of accident risk (from perhaps one in 10^6 to one in 10^7), *yet we chose not to make the increase for economy reasons.* There is much work yet to be done to systematise this linking of safety and economy but the reality of the link is very clear.

Another important feature of this linking of safety and economy has been brought out recently by A. E. Russell[20]. Discussing some safety aspects of the current aeronautical problem of the gradual, but sometimes sudden, cracking of pressure cabin plating, and the like, he has emphasised the importance of an adequate system of inspection to ensure that repairs are effected before a critical situation is reached. In a structure that is designed so that some cracking is not initially and automatically catastrophic—a "fail-safe" structure—it is possible to choose an inspection period so that the

TABLE II

DESIGN LOADS FOR DAMAGED FAIL-SAFE STRUCTURES

Inspection period (Flying hours)	*Design load for damaged structure (per cent of ultimate strength of undamaged structure)*
8	49
58	58
250	65
3,000	78
30,000	91

Loads given to provide a chance of 100 to one against meeting the load between inspections.

risk of collapse of the cracked structure is controlled to a prescribed low standard. This can only be done, of course, if the load history is known. Taking such a case, Russell has produced a table like Table II. From this it is seen that, if the chance of collapse of the damaged structure between inspection periods is to be limited to one in 100, inspection every 3,000 flying hours will be adequate for a structure reduced to not less than 78 per cent of its design ultimate srength; but an eight-hourly inspection would be necessary were this percentage to fall to 49 per cent. Here is another aspect of our problem that introduces inspection periods and costs into the linking of safety and economy.

8. Conclusion

Let me conclude by a quotation from Brunel,[21] a Bristolian by adoption like Barnwell. With his usual quick perception for essentials, he wrote, when explaining his checking of Scott Russell's detailed drawings for the hull of the Great Eastern: "I found for instance an unnecessary introduction of a filling piece of strip such as is frequently used in shipbuilding to avoid bending angle irons—made a slight alteration in the disposition of the plates that rendered this unnecessary and found that we thus saved 40 tons weight of iron, or say £1,200 of money in first cost and 40 tons of cargo freight—at least £3,000 a year.

"The principle of construction of the ship is in fact entirely new if merely from the rule which I have laid down and shall rigidly preserve in that no materials shall be employed on any part except at the place and in the direction and in the proportion to which it is required and can be usefully applied for the strength of the ship and not merely for the purpose of facilitating the framing and first construction . . . All this misconstruction I forbid and the consequence is that every part had to be considered and designed as if an iron ship had never been built before; indeed I believe we should get on much quicker if we had no previous habits and prejudices on the subject."

One can almost hear a modern aeroplane designer talking; we in Bristol and elsewhere owe a lot indeed to pioneers like Brunel, not least for promoting the study of the economy of structures; and in our own field, as Barnwell himself concluded, "a vast amount of work may be put most usefully into research as to economic conditions, for of all engineering structures the aeroplane is that one on which we can least afford to waste any weight or efficiency."

REFERENCES

1. Claxton Fiddler, T. (1887). *A practical treatise on bridge construction.* Griffin, London, 1887.
2. Stoney, B. B. (1873). *Theory of strains in girders and similar structures.* Longmans Green, London, 1873.
3. Matheson, E. (1873). *Works in iron.* E. & F. Spon, London, 1873.
4. Merriman, M. and Jacoby, H. J. (1917). *A text book on roofs and bridges.* Wiley, New York, 1917.
5. Pippard, A. J. S. and Pritchard, J. L. (1919). *Aeroplane Structures.* Longmans Green, London, 1919.
6. Barnwell, F. S. (1919). Some points in aeroplane design. *The Aeronautical Journal,* June 1919.
7. Wagner, H. (1931). *Flat sheet metal girder with very thin metal web.* English translation, N.A.C.A. T.M. Nos. 604, 605, 606, 1931.
8. Shanley, F. R. (1952). *Weight-strength analysis of aircraft structures.* McGraw-Hill, New York, 1952.
9. Gerard, G. (1954). *Minimum weight analysis of compression structures.* University Press, New York, 1954.
10. Russell, A. E. (1949). Aircraft materials from the designer's point of view. *Second International Aeronautical Conference,* New York, 1949.
11. Cox, H. L. (1958). Structures of minimum weight: the basic theory of design applied to the beam under pure bending. A.R.C. Unpublished Report T, 19,785, 1958.
12. Pugsley, A. G., Tye, W. and Allwright, H. J. (1949). The structural and aerodynamic effects of wing thickness and fuselage size variation. A.R.C. R. & M. 2377, 1949.
13. Gardner, G. A., Morton, R. and Creasy, L. R. (1953). Economy in the use of structural materials. *Journal of the Institution of Structural Engineers,* 1953.
14. Clarkson, J. (1956-57). The design for minimum weight of simply supported flat grillages to withstand a single concentrated load. *Trans. N.E. Coast Inst. of Engrs. and Shipbuilders,* Vol. 73, 1956-57.
15. Horne, M. R. (1952). Determination of the shape of fixed ended beams for maximum economy according to plastic theory. *Fourth Congress of Intern. Assn. Bridge and Struct. Eng.,* Cambridge, 1952.
16. Foulkes, J. (1954). The minimum weight design of structural frames. *Proceedings of the Royal Society, A.* Vol. 223, 1954.
17. Heyman, J. (1951). Plastic design of beams and plane frames for minimum material consumption. *Quarterly Journal of Applied Mathematics,* Vol. 8, 1951.
18. Pugsley, A. G. (1955). Structural safety. *Journal of the Royal Aeronautical Society,* June 1955.
19. Pugsley, A. G. (1957). Design for safety and efficiency. *Journal of the Institution of Structural Engineers,* 1957.
20. Russell, A. E. (1957). Safety in relation to structural damage. *Sixth Anglo-American Aeronautical Conference,* Folkestone, 1957. *To be published* 1959.
21. Rolt, L. T. C. (1957). *Isanbard Kingdom Brunel, a biography.* Longmans Green ,London 1957.

Drone Aircraft†

by

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1. Introduction

It is necessary to start this paper with a disclaimer. Neither the author nor his firm have been concerned with the development of Drone aircraft for more than a few years. Others in the field have more, certainly longer, experience; the choice of the present author is probably because he has been associated with the development of the most ambitious target aircraft so far produced in Britain—the Canberra Mk. 10.

The early history of work on automatic flight was discussed by Dr. G. W. H. Gardner in the 46th Wilbur Wright Memorial Lecture*. Credit is due to the Royal Aircraft Establishment for the development of more modern Drones and associated equipment, and indeed, of the whole control system which is now used for Aberporth and in Australia. Much credit is also due to the Australian authorities for the working up of the target service which they now provide at Woomera and for the development of the Jindivik target. The Fairey Aviation Company Ltd. and Flight Refuelling Ltd. have respectively been concerned with the droning of the Fairey Firefly and the Gloster Meteor aircraft which are also used as targets for British missiles.

The weapons which have preceded the guided missile (*e.g.* aircraft and artillery) have largely been developed by usage, partly by test flights and exercises of the aircraft or trial firings of the gun, and partly by curing the mistakes made during the early phases of a war, the pace of which has in the past invariably enabled this to be done. The advent of the defensive guided missile, however, presents new problems, partly because of the relatively high cost of the missile which limits its availability and partly because the type of attack which the missile is intended to deal with may well be most ambitious and "sophisticated." In this age of deterrents, it can be said that a deterrent (at any rate an anti-aircraft deterrent) is only a deterrent if it is likely to be effective when called upon to operate. Unless the enemy feels that the state of readiness and reliability are reasonably high, he is not likely to be greatly "deterred" by G.W. defence.

Taking all these factors into account, it is obvious that ensuring that guided missiles can achieve the required objectives is of vital importance, and hence there is a need for drone aircraft to reproduce as faithfully as possible likely forms of attack.

*Automatic Flight—The British Story, *Journal of the Royal Aeronautical Society*, July 1958.

†The seventh lecture given to the Astronautics and Guided Flight Section of the Society—on 17th December 1958.

2. Purposes of Target Aircraft

There are three main duties of target aircraft—research work, reliability-proving and Service training.

An assessment of what a typical modern A.A. missile is likely to be required to do can be made by considering the sort of attack which an enemy is likely to mount. The sort of attack which might be expected now and, say, in 1965, might conveniently be assumed on a basis that the enemy's abilities and knowledge of aircraft design are approximately those of our own designers. It is known, for example, that currently operational heights in excess of 50,000 ft. can be achieved and it therefore follows that, if progress in the field of aircraft development continues at a rate commensurate with the achievements of recent years, operational heights approaching the known maxima for orthodox aircraft will be achieved within the space of a few more years. Thus long range attacks at increasing speeds and altitudes well in excess of 60,000 ft. must be catered for. On the other hand, the possibility of low level high speed attacks over relatively short distances must not be ignored. It is reasonable to assume, therefore, that guided missiles are being developed to deal with all sorts of targets and forms of attack; thus it follows that reasonably true representations of such targets should be available to facilitate a full and detailed evaluation of guided missile performance envelopes.

The second factor dictating the provision of drone aircraft is the factor of missile reliability. As any practical aircraft engineer knows, there is a world of difference between an isolated or even a frequently repeated test result and the sort of reliability which is required for the airline operation of an aircraft or the service use of a guided missile. It is probable that nothing less than 200 or 300 firings of a typical missile system against real targets would ensure that the missiles have an adequate reliability under field conditions. There is a parallel here with aircraft experience, which is that even after several thousand hours of development flying, the faults which occur when an aircraft gets into airline service are many and are usually quite unpredictable; many are minor, although serious in their inconvenience.

The aircraft flight development engineer is sure after several thousand hours of flying that the snags have been discovered in the prototype aircraft, and the missile test engineer will feel the same after many hundreds of laboratory tests, but probably the Army or Air Force missile officer is going to be in the same position as the airline operator who discovers a host of new snags as soon as the aircraft gets into service. In the author's

opinion, the tendency noted in many quarters today to argue that simulation studies or practising with dummies can take the place of the real thing is extremely dangerous and pernicious.

The third purpose of target aircraft is for training. The Services must train their men and crews and carry out exercises from time to time. While much of this can usefully be done with dummies, particularly in relation to servicing and handling, the final requirement is the real thing. For this purpose also, drone aircraft will be required, although perhaps not of the ambitious type that the research phase requires.

3. Types of Existing Target Aircraft

There are many types of existing target but they can be classified broadly into four categories: —

(*a*) *Small, cheap, low performance targets.* There is still today a demand for a simple low performance target derived directly from the Queen Bee described by Dr. Gardner. Typical in this category is the French CT.10 which has been developed from the V.1 and is in use in the Mediterranean by the Royal Navy; another is the American Radioplane OQ.19 (Fig. 1). These targets are of low speed and ceiling with an endurance of up to about one hour. They can usually be launched off a rail system and recovered from the sea for re-use.

(*b*) *Droned surplus aircraft.* The droning of surplus or obsolescent aircraft is a common method of providing realistic targets. In Britain we have the Firefly 9, the Meteor 15 and 16 and the Canberra 10 aircraft based on conversions of obsolete marks of these aircraft. In the U.S.A. there are the QB.17 and the QF.80 Shooting Star, with the B.47 coming along as a new requirement.

The Meteor is a good modern target in this category with a ceiling of about 35,000-40,000 ft., an endurance of about 1¼ hours and a maximum speed of about 450 m.p.h.; it is also of relatively low cost. The Canberra is more ambitious and is relatively expensive, although justified on account of its large and more representative size and its good altitude performance, as mentioned later. The important point to appreciate in relation to surplus aircraft however is that of necessity they are always one generation behind in design and performance as compared with the type of aircraft which the enemy is going to attack you with—if they were not they would not be surplus. A further difficulty is that there is unlikely to be any surplus of supersonic aircraft for some time to come; indeed the provision of target aircraft is going to become increasingly difficult as the missile replaces the manned aircraft in the R.A.F.

FIGURE 1. Typical small, inexpensive target—the Radioplane OQ.19 with four-cylinder piston engine. Endurance one hour at 20,000 ft. Max. speed 210 m.p.h., max. altitude 30,000 ft. 11 ft. 6 in. wing span. Parachute recovery.

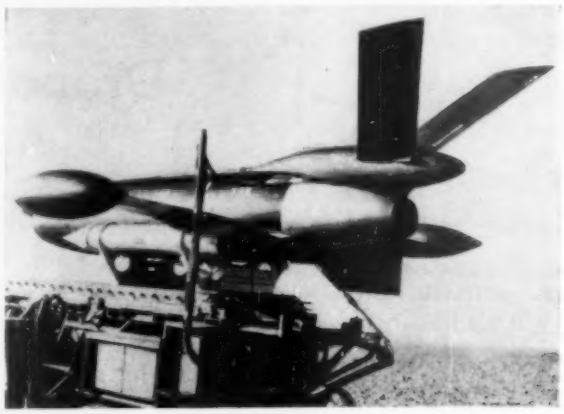

FIGURE 2. The French CT.20 target. Marboré turbo-jet engine. Endurance 45 min. Max. speed 560 m.p.h., max. altitude 40,000-46,000 ft, depending on engine type. 11 ft. wing span. Parachute recovery.

(*c*) *Small specially built targets of good performance.* An extension of the first category is a series of targets, of much more ambitious conception although still of relatively low cost, designed for reliability-proving and training. The Australian Jindivik, the French CT.20 (Fig. 2), the Ryan Firebee and the Radioplane RP.77 (Fig. 3) are typical targets in this category. They are all subsonic with an endurance of about an hour, rail-launched and with parachute recovery. The published price of the CT.20 is about £16,000; this is probably relatively inexpensive for a target of this type (about twice this figure seems more probable) but shows why they are preferred to drone aircraft for training work.

(*d*) *Supersonic targets.* Because the development of a special target aircraft would be prohibitively expensive, and because there are no supersonic aircraft which are surplus, it has been necessary to develop special small supersonic missile-like targets using rocket motors or ram-jets. This is a relatively new development, the Lockheed Q.5 (Fig. 4) being typical of what can be achieved. There is reported to be a development of the French CT.20 in this category and other countries are likely to be considering similar developments. Air launching from a mother

FIGURE 3. The Radioplane RP.77 with Boeing 502-10 free turbine engine. Endurance one hour at 40,000 ft. Max. speed 425 m.p.h., max. altitude 47,000 ft. 15 ft. wing span. Parachute recovery. Fibre glass structure.

aircraft may be considered desirable as a convenient method of getting the target to altitude and also (perhaps more important) to provide a satisfactory long holding-time while the missile system is being got ready for the actual firing: this is referred to again. Any supersonic target will be expensive and air launching also will involve a substantial "overhead" cost.

4. Missile Problems Affecting Target Choice

4.1. ALTITUDE

Aerodynamic manoeuvre performance, both of the aircraft being attacked and the attacking missile, falls off considerably with altitude. Rather than build a target to operate at the correct altitude for which the missile is being designed, it might be argued that simulation at a lower altitude might be possible. This presents a number of practical difficulties.

A high altitude bomber may be designed to give, say, $1\frac{1}{2}$ or $2g$ manoeuvre at 60,000 ft. This means that for the same control deflection at lower altitudes the acceleration will increase appreciably (*see* Fig. 5). An acceleration limit will be imposed either by the pilot or the structure.

Similarly, the available missile acceleration will increase with reduction of altitude. Providing we operate at an altitude equal to, or above, that imposed by the limit on the aircraft, the ratio of the missile to aircraft acceleration will be maintained and, furthermore, the incidences required will be the same as those utilised for maximum acceleration at 60,000 ft. Unfortunately, response (involving inertia, and the height-dependent aerodynamics) is not the same at this lower altitude. Active and semi-active guidance systems are very dependent on responses and to retain the correct simulated response, modifications must be made to the missile.

At heights below those imposed by the aircraft limit, the correct acceleration ratio could be achieved by including a limit in the missile. This would result, however, in incorrect missile incidences. To retain the correct missile incidences as well as the correct accelerations, a change in missile configuration would be needed. As before, it would also be necessary to achieve the correct responses. Even having done all this, the aircraft target would not be flying at its maximum incidences which would affect such characteristics as radar echoing area, jitter, glint, and so on.

In a controlled cruciform missile the demands are

FIGURE 4. The Lockheed Q.5 supersonic target. Ram-jet motor mounted underneath at rear. Speed $M=2+$, altitude 60,000 ft.+, length 39 ft. Air-launched from B.50.

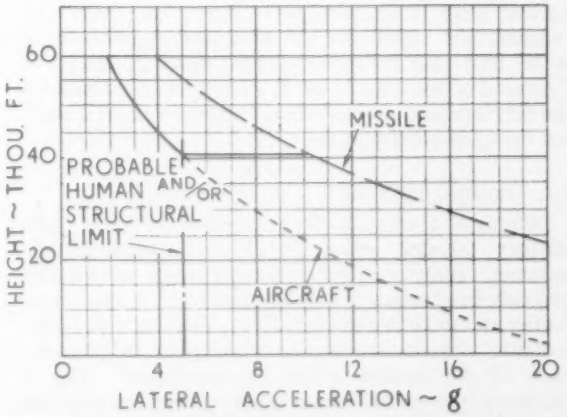

FIGURE 5. Typical relative acceleration capabilities of missile and aircraft at varying altitudes.

resolved into the two components in the planes of the wings. Owing to the mechanical and electrical connections in the missile a movement or demand in one plane usually induces a small component in the opposite plane, *i.e.* cross-coupling. Its effect will be more pronounced at high altitude where high body rates and angles are involved. The proving of the missile, at least in the research phase, must therefore include attacks at representative high altitudes.

As already indicated, anti-aircraft missiles of the next generation must be able to intercept at altitudes considerably in excess of 50,000 ft. Probably no target aircraft so far developed, other than the Canberra 10, is capable of exceeding 50,000 ft., although the latter can exceed it by a handsome margin. Indeed the main justification for its development is the excellent performance of the aircraft at altitude.

4.2. SIZE

The size of the target is of considerable importance to the missile radar control or homing system. Although there are artificial methods of simulating glint or scintillation caused by the spanwise or lengthwise distribution of the reflecting surface of the aircraft, these are bound, on a small missile, to be limited by the physical wing span of the target; simulation also involves the problem of introducing the required randomness of operation. A real drone aircraft has the advantage therefore in being realistic in relation to the reflecting area and the distribution of the principal masses. It may be possible to determine from a few test results that the missile system works satisfactorily with a simulated reflecting area and thus only a part of the research work must be done on a representatively large target. This seems particularly true of fuse trials since there can be no guarantee until tests have been made that the fuse will work satisfactorily on a large target and on a small one.

4.3. SPEED

Steady target speed does not seem to be of any great consequence, mainly because of the relatively high speed of the attacking missile, but manoeuvrability needs to be representative. Broad bands of speed are all that seem to be necessary, *e.g.* low subsonic, high subsonic and supersonic ($M=2$ approx.); there seems to be little case for developing a supersonic target at the speed of less than $M=1{\cdot}5$. Target requirements for the development of anti-ballistic missiles are, of course, not being considered here.

4.4. HOMING SYSTEMS

Radome aberration is a constant difficulty with homing missiles unless fitted with hemispherical radomes. Representative deviations of the radome axis will only be obtained if the body incidence of the missile during an attack is representative. Thus tests at representative altitudes are necessary to prove the performance of the missile under all conditions. Fig. 6 illustrates radome aberration effects—beam bending and aberration instability—both sensitive to radome axis deviation.

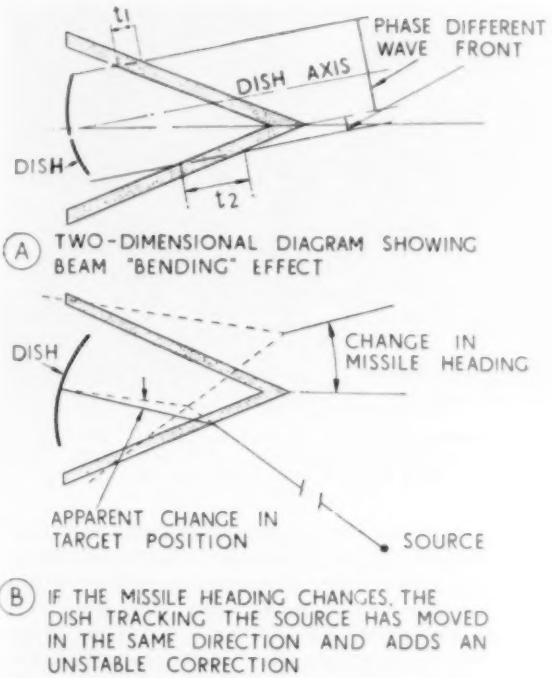
t1
PHASE DIFFERENT WAVE FRONT
DISH AXIS
DISH
t2
A TWO-DIMENSIONAL DIAGRAM SHOWING BEAM "BENDING" EFFECT
DISH
CHANGE IN MISSILE HEADING
APPARENT CHANGE IN TARGET POSITION
SOURCE
B IF THE MISSILE HEADING CHANGES, THE DISH TRACKING THE SOURCE HAS MOVED IN THE SAME DIRECTION AND ADDS AN UNSTABLE CORRECTION

FIGURE 6. Radome aberration effects.

4.5. ENDURANCE

One of the major problems during research trials of missiles is a practical one, namely, that the missile has not yet got to the stage of development when it can be fired instantly without a certain amount of preparation. Thus under practical trial conditions, the target aircraft may be asked to hold-off, after take-off and climb to height, in case last minute difficulties do not enable the missile to be fired at precisely the right moment. The ability to orbit in the sky for anything up to two or three hours is a considerable advantage in the practical use of targets and is one reason why ground-launched supersonic targets are not likely to find much favour for some time.

On the other hand, an air-launched missile target can be used by allowing the radar tracking system of the attacking missile system to lock on to the mother aircraft carrying the target and thus permit the simulation of attacks from long range. Depending on the range of the target itself, air launching is then carried out to simulate the final phase at the appropriate altitude, probably much greater than that of the mother aircraft. It is possible to separate the reflection of the target from that of the aircraft after launch allowing the radar to continue to track the target while the mother aircraft returns to base. This system can thus allow for adequate endurance of the target system with limited endurance of the final element.

5. Brief Description of the Canberra 10 Target

It may be of some interest to give a brief description of the Canberra 10 to illustrate the sort of changes that

have to be made on an aircraft in order to convert it to a drone.

The Canberra 10 is a conversion of the early English Electric B.2 series aircraft. The popular idea that a drone aircraft can be in a worn-out or poor condition has not proved practicable, partly in the case of the Canberra because the aircraft has to be ferried by air to Australia, but mainly because in practical operation at a range, delays due to unserviceability of the target can waste missile time and money out of all proportion to the cost of keeping the aircraft in a serviceable state. Thus the expected life of a Canberra Drone when converted is of the order of 300 hours; many piloted flights will be required for range and ground equipment proving work and, depending upon the type of trials for which it is used, many target sorties are expected before the aircraft may be lost or killed. It will be appreciated that many of the early trials can be conducted in such a way that the destruction of the target can be deliberately avoided. Nevertheless, the overhaul standard of the aircraft must be related to this life expectancy.

The two major changes in the Canberra, apart from the installation of the subsidiary automatic control equipment, are the fitting of an auto-pilot (none being used on the B.2 series aircraft) and of cameras for miss distance indication (M.D.I.). As discussed later the special B.3 auto-pilot, developed originally by the Royal Aircraft Establishment for Jindivik and other targets, has been adapted and installed in the aircraft as the basis of the control system. Australian cameras of ingeniously simple design have been used.

The full performance envelope of the basic aircraft is maintained, giving speeds of about $M=0{\cdot}8$ at an operational ceiling in excess of 55,000 ft. and an endurance of about three hours. The all-up weight of the aircraft is, of course, considerably reduced compared with the operational aircraft since there is no service load.

The main equipment to be added to the aircraft and installed, as shown in Fig. 7, comprises: —

(*i*) Auto-pilot and air speed control units and servos for elevator, rudder and ailerons.
(*ii*) Radio link receivers and coupling units.
(*iii*) Cameras in wings, and calibrating devices.
(*iv*) Actuators for throttles and fuel cocks.
(*v*) Automatic anti-skid brake equipment and electrically-operated brake selection gear.
(*vi*) Telemetry equipment to display main aircraft instrument signals to the Master Controller on the ground (engine speeds, height, air speed, and so on).
(*vii*) Destroy system to enable aircraft to be broken up in flight if necessary, for safety reasons.
(*viii*) Subsidiary press-button panel in cockpit to enable remote control flight to be simulated by a pilot during test flying or rehearsals. (This is essential for the practical development and working-up of a target system.)
(*ix*) Beacon or Transponder to assist ground tracking—a standard missile tracking system (M.T.S.) equipment is used.

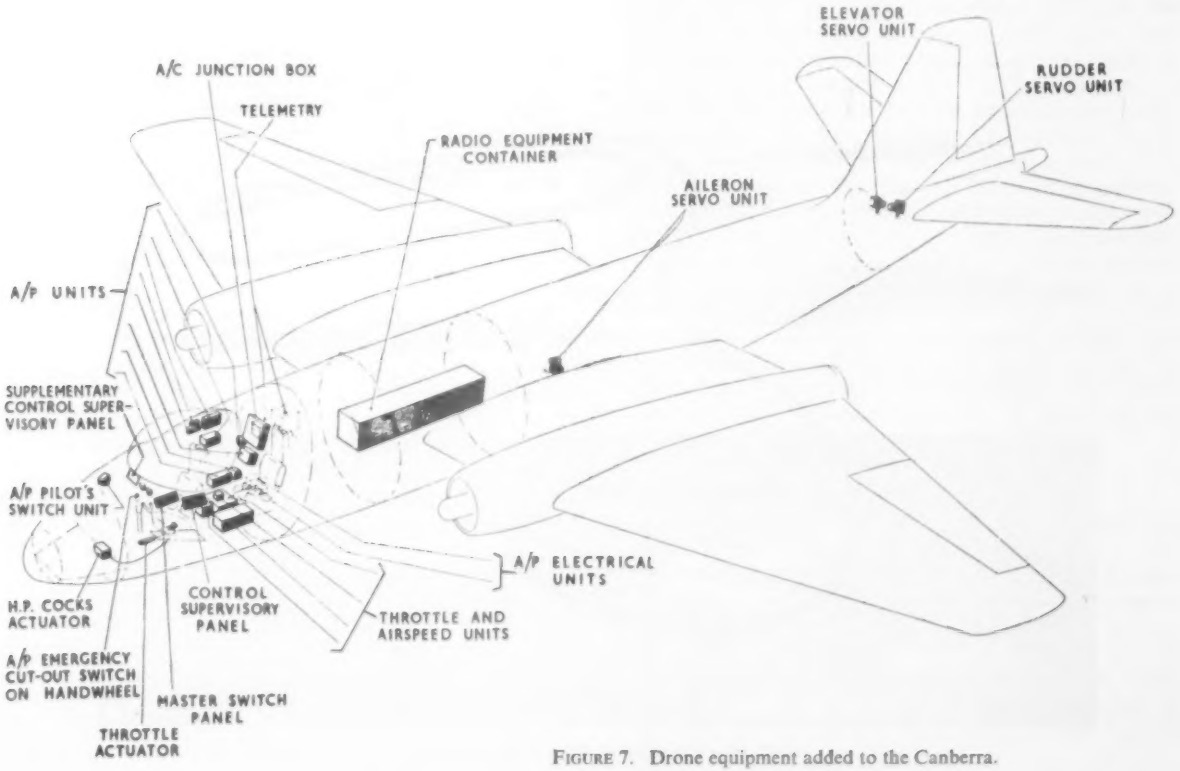

FIGURE 7. Drone equipment added to the Canberra.

(x) (In some aircraft) a drag parachute for shortening the landing run.

The more interesting features of this equipment are now referred to.

6. Target Control Systems

The most difficult part of the development of a target control system is undoubtedly the landing phase. The British control system, originally evolved and applied by the Royal Aircraft Establishment and put into use most effectively in Australia by the R.A.A.F., makes use of a particular landing technique, suitable also for take-off, and relies on radar tracking to indicate the positions in space of the target when out of sight. The radio link is by V.H.F., this implying a "line of sight" control up to ranges of about 150 miles (low level control at long range or over hilly territory is thus impossible). Telemetry is used to repeat essential aircraft instrument readings to the "pilot" on the ground because he may be able to anticipate trouble or recover an aircraft which is out of control or not responding correctly to signals. It also enables him to vary flying speed easily.

There are three possible automatic landing systems known to the author—there may be others but they are probably variations of one of these three.

There is the B.L.E.U. automatic landing system; this uses conventional I.L.S. equipment for the approach to 300 ft. monitored by Precision Approach Radar (P.A.R.); magnetic leader cables to control direction below 300 ft. and a radio altimeter to control elevation and to initiate a flare-out from 20 ft. to touch-down. Drift as read from a compass can be kicked-off just before touch-down. Although not so far attempted, taxying and take-off could be controlled by leader cables.

There is also an American (Bell) system with the same objective as the B.L.E.U. system, using a lock-on radar set which picks up the aircraft at a given range and computes the error between the required and the actual position down the glide path and sends signals by radio link to the aircraft to initiate motions to cancel the error.

Both of these systems have been developed to permit automatic landing in zero visibility conditions; the drone control system, however, is intended for pilotless operation in conditions of good visibility (or on a clear night) since the chances of fog at the range are much less than at civil airports in urban areas.

The British target control system, as already indicated, uses a master controller or "pilot" to control the aircraft in flight by pressing buttons on a panel in a control van on the range aerodrome; a typical sortie pattern is illustrated in Fig. 8. Automatic landing is initiated by P.A.R. tracking and "button-pressing" until the aircraft is lined up correctly and approaching in the landing-glide attitude on a 2° path from a range of about 5 miles. The aircraft now comes under the control of optical sighting equipment sited on the airfield. The equipment comprises two binocular sights, respectively for azimuth and pitch. The pitch sight operator is provided with a "beep" up/down control switch and a "fuel-off" control. Pitch control of the aircraft, during approach and landing, is achieved by

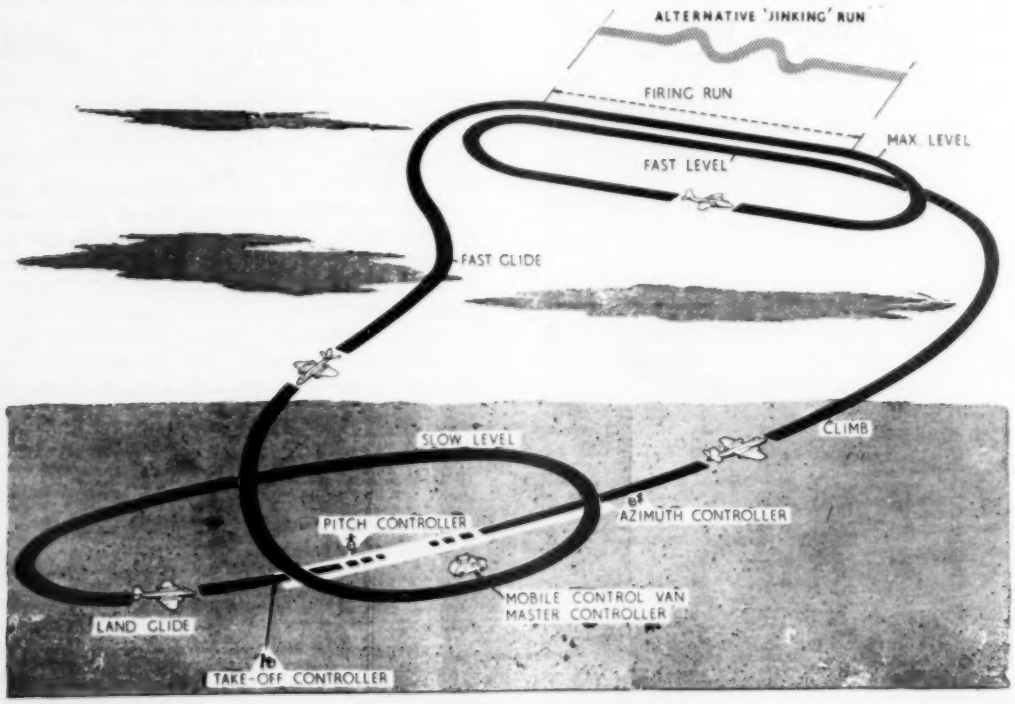

FIGURE 8. A typical target sortie pattern.

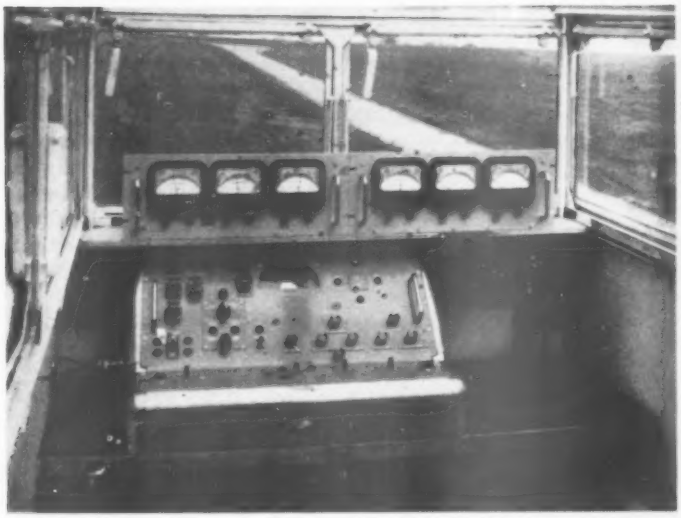

FIGURE 9. The master control panel used with the Canberra 10.

FIGURE 10. A typical runway sight.

the operator maintaining the aircraft on a predetermined glide path—as indicated by a graticule in the binoculars. The azimuth sight operator is provided with a left/right control switch only and maintains the aircraft heading relative to the runway centreline by a vertical graticule reference in the binoculars.

At take-off, azimuth control is maintained by means of the optical reference, while the pitch axis is controlled automatically by the aircraft control gear in accordance with a pre-set programme.

The responsibility for the control of the aircraft during the entire operation rests with the Master Controller. He can transfer command to the optical sight operators, during take-off and landing, and personally controls the transmission of aircraft attitude and "beep" signals (*see* later). Additionally, he is responsible for the navigation of the aircraft, in conjunction with the radar network. The operational team thus numbers three men as follows: —

(*i*) Master Controller.
(*ii*) Pitch Sight Controller who also acts as Take-off Controller.
(*iii*) Azimuth Sight Controller.

6.1. THE LANDING PROCESS

The aircraft is fed into the approach pattern by radar and/or tracking control in the "slow level" condition (an explanation of the "fixed attitude" terms is given later). A glide path angle of 2° is employed as already mentioned; this corresponds to an altitude of 1,000 ft. at 5 nautical miles from touch-down.

(The touch-down vertical speed is slightly higher than with a conventional flared-out landing but is well within the capability of the Canberra landing gear; the aircraft has extremely good natural characteristics under this type of landing, and landings appear better than the theoretical 6 ft./sec. vertical velocity which an approach at 110 knots gives.)

The aircraft is "beeped" (*see* later) down to this altitude from 2,000 ft. during the initial traffic pattern, while in the "slow level" condition, after transition from "fast glide." At about 7 miles, the "land glide" command is selected and the aircraft enters the glide path at approximately 5 miles. Normally the ground operators will be in visual contact at this point but, should this not be so, the Master Controller will continue supervising the approach down the glide path by reference to radar and telemetered information until visual contact is established. Once the ground operators have established contact, control is handed over to them, the final approach phase being completed under their control. All three operators are in mutual "intercomm." communication. The overshoot control possibility is retained by the Master Controller throughout. The aircraft "flies on" from the glide path, the approach speed, rate of sink and glide path angle being carefully selected to allow this; if desired, a flare-out can be effected by "beeping" UP immediately before touch-down, but this is not essential. Control during the landing roll is maintained by the azimuth operator who is provided with a differential brake rudder control; the anti-skid braking system is fully automatic in operation. The "fuel-off" command, however, is originated by the Master Controller.

6.2. THE TAKE-OFF PROCESS

The aircraft is lined up on the runway and the Master Controller initiates the take-off signal. The aircraft is controlled in azimuth by the take-off controller by rudder control, as in the case of the azimuth operator during landing; no binocular sighting equipment is used. The pitch control is in accordance with a pre-set programme coming into operation when flying speed is reached. When the Master Controller considers it opportune he will assume full control of the aircraft and continue with the flight plan.

The drone system is thus automatic in the sense that the aircraft is pilotless but requires three operators on the ground (plus radar tracking) to permit landing and take-off; obviously an experienced and well co-ordinated team of men is needed. The B.L.E.U. system could be adapted for fully automatic operations but the need for leader cable installations along the whole of the runway and all approaches would out-weigh the advantages of eliminating the two sight operators. The American lock-on radar system might be more attractive in this respect since it is presumably flexible in its siting, but suffers from the basic disadvantage that the radar signals are bound to suffer at close ranges, near the ground, as compared with the optical sighting which tends to increase in accuracy at closer ranges.

Figure 9 illustrates the Canberra control panel used by the Master Controller; Fig. 10 shows a typical runway sight, with binoculars arranged with their optical axis (*i.e.* a graticule) set-up to determine the required glide path.

7. The Aircraft Guidance or Remote Control System

The essential principle of the R.A.E. target "guidance" system is to divide the flight plan, as shown typically in Fig. 8, into a number of distinct phases in order to simplify the control system. In practice, although the sequence of events when the ground controller demands a change may be predetermined, he can also fly the aircraft over any required pattern within the basic capability of the aircraft and the range of the radio link (about 100 miles) by "beeping" (*i.e.* giving short pulses or bursts of control) from one state to another.

The phases of flight are known as "fixed attitudes" and are as follows: —

(*a*) *Climb*—climbing at a predetermined rate.
(*b*) *Slow level*—conventional level flight at low power settings.
(*c*) *Fast level*—flight at maximum cruising speed.
(*d*) *Fast glide*—a relatively fast rate of descent similar to the instrument let-down of a conventional aircraft.
(*e*) *Land glide*—a constant approach speed at an approach angle of about 2° and so arranged that the aircraft can fly on to the runway without levelling-off if necessary.
(*f*) *Overshoot*—similar to the equivalent condition on an ordinary aeroplane when a landing has to be discontinued.

(There is also an *Emergency Approach Condition*—a single-engine approach, but this is not really a "fixed attitude.")

When any one of these attitudes is demanded, the control system is such that a particular sequence of events takes place to maintain the aircraft steadily in that particular attitude. For example, when *climb* is selected at the beginning of a take-off, the engines will open up to the appropriate maximum r.p.m., the wheel brakes will be released slightly before the full power is reached and the aircraft will move down the runway under the directional control of the take-off Controller and the auto-pilot. At a particular air speed, as measured by Pitot pressure, the aircraft is lifted off the runway and then the landing gear retracts automatically. A momentary application of wheel brakes just before retraction begins ensures that the wheels have stopped rotating.

The flaps are automatically extended on the selection of *land glide*, there being a speed safety switch to initiate flaps-up should the speed rise above a given speed. Dive brakes extend if the speed becomes excessive.

In addition to the fixed attitudes, the Master Controller on the ground can select further manoeuvres within these attitudes as follows: —

Right and left turn, straight, climb and descent, fuel off, flaps up, fine turns, high banked turns, throttle open/shut and tail-plane setting. By controlling the time of application ("beeping") he can obtain a great measure of control of the flight programme. The whole process is surprisingly smooth, most of the manoeuvres being executed with a precision that the normal pilot would have difficulty in bettering.

7.1. THE RADIO LINK

The radio control system used in Britain and Australia relies on V.H.F. with a duplicate receiver in the aircraft to give an emergency link for the command destroy system. Future developments will, no doubt, use U.H.F. as being less susceptible to interference from other transmission (this is not, however, a serious problem at Woomera).

The transmitter passes intelligence to the aircraft by means of a series of pairs of "tones" or particular frequency transmissions. A "tone" generator having an oscillator fundamental frequency of 400 c./sec., suitably distorted to be rich in harmonics, produces an octave of tone harmonics of 400 c./sec. These eight tones can produce $8 \times 7/2 = 28$ separate tone pairs, although in practice some are not used; each pair of tones corresponds to some command, the circuits being arranged for safety reasons so that if more or less than two tones are received no output occurs; also one tone pair is a "guard pair" of higher than normal sensitivity so that receiver noise is also blocked by this pair operating.

During normal flight the tone pairs are transmitted one at a time since the master controller will only select one action at a time. During landing, however, it is necessary to transmit signals from both pitch and azimuth controllers simultaneously. A second tone generator is now brought into operation and the transmitter switched rapidly from one generator to the other alternatively, with a short dwell period on each. The relays in the aircraft receiver are slugged to allow them to hold on over this period so that effectively the receiver is in continuous contact with both transmitters.

In the aircraft the signals picked up by the receiver are passed to a relay set (commonly called the R.S.R.—"Relay set receiving") where the tone pairs are sorted out by means of tuned filters and operate appropriate relay chains to initiate the desired command. These

relays thus send the appropriate signals to the auto-pilot, air speed unit or other actuators on the aircraft, or operate the cameras or destroy system. When a particular relay is operated to give a particular fixed attitude, the other relays corresponding to different fixed attitudes are cancelled. Once selected an attitude remains in force until cancelled by another selection. Those actions which are "beeped" (*e.g.* right/left turn, pitch up/down, and so on) have non-holding relays and control is only applied as long as the ground controller holds down the appropriate switch.

8. The Aircraft Control System

Figure 11 shows the main features of the aircraft control system in diagrammatic form. The main elements are an auto-pilot, an air speed and throttle servo system and the input signals from the radio link already mentioned. The auto-pilot is an Elliot type B5A with yaw, pitch and roll units and electro-magnetic servo units.

This auto-pilot, developed originally by the Royal Aircraft Establishment for target aircraft use, has been modified somewhat for the Canberra and in practice could be simplified if time and opportunity permitted. Pitch angles of up to $\pm 30°$ and bank angles of about 70° are provided. The basic platform carries a position gyro to provide master vertical or attitude information, a rate gyro for damping purposes on the roll axis, and also a turns computer. Signals from the radio link demanding banked turns alter the platform position to initiate roll, the turns computer resolving the solid trigonometry involved and feeding in rudder and elevator compensating signals, and a further compensating augmentation pitch signal to the elevator to correct for height loss in a banked turn.

Small or fine turns are made by a direct voltage being fed to the yaw rate gyro which is mounted rigidly to the aircraft structure, and thus effectively moves only the rudder.

What was intended originally to be a pitch platform is used only as an expedient means of mounting a pitch damping rate gyro and a motor-driven potentiometer, to provide a means of varying the demanded pitch attitude, the pitch position signal being obtained from the vertical gyro on the main platform. In another project more use might be made of condensor differentiation of attitude data to provide damping terms, as the present system seems rather complicated (*i.e.* four gyros).

Gyro currents are amplified in a series of magnetic amplifiers and then passed to the servo motors (*see* later). Small tacho-generators in the latter provide rate feedback for stabilisation.

The air speed system consists of a number of pressure capsules giving a series of fixed or variable voltage references to control height or speed and to enable certain height/speed relationships (*i.e.* "laws") to be maintained. The actual speed capsule feeds a throttle amplifier and servo to regulate engine power.

Air brakes are operated by air speed error, flaps and landing gear by direct or pre-determined command, with over-riding safety speed operation.

The conventional method of controlling an aircraft automatically on blind approach (as at B.L.E.U. and earlier British Drones) is to use elevator control to fly the aircraft up or down to the required approach path (*i.e.* pitch sight operator's optical axis); thus the operator moves the pitch platform directly while the air

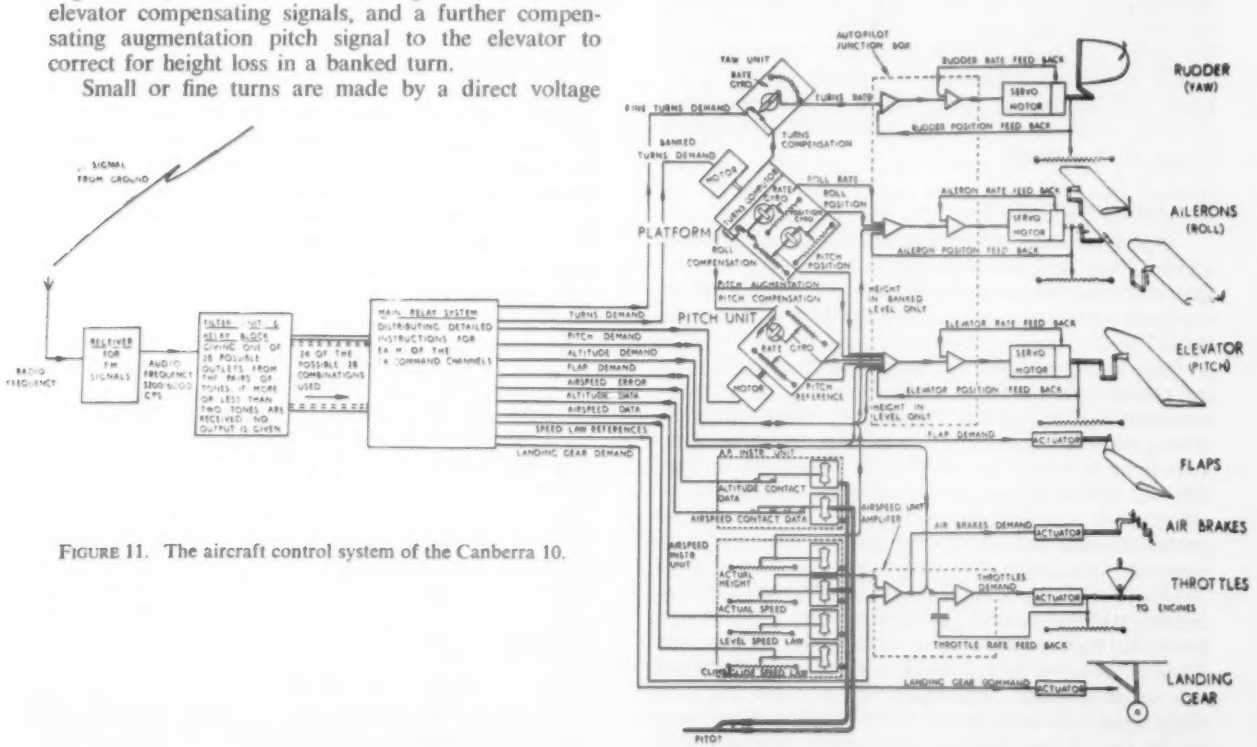

FIGURE 11. The aircraft control system of the Canberra 10.

speed control system varies the throttles automatically to keep the speed constant. As a result of flying experience on Canberras, a decision was taken to reverse this process for the Canberra 10, and to use the system commonly used for deck landing, *i.e.* direct use of throttles to fly back up to the path, or to allow the aircraft to sink down to it, while the air speed unit maintains the speed of the aircraft constant by variations of attitude in pitch. This gives much better overall response, at any rate on the Canberra, and allows a reasonably low approach speed.

The auto-pilot electro-magnetic servos make use of constantly rotating electric motors driving a pair of clutches which are energised magnetically to obtain rotation in one direction or the other. In order to hold a load, as is necessary on the Canberra elevator circuit during certain flight modes, the clutch must be kept in a continually slipping condition. Some difficulties have been experienced with this system mainly due to variations of coefficient friction of the clutch plates, a difficulty well known to mechanical engineers.

The fitment of an auto-pilot to an aircraft such as the Canberra in the late stage of its development life often presents problems, particularly since the margin between servo power required to carry out the maximum desired manoeuvres and that which, under runaway conditions, may prove dangerous, may not be very great. A hydraulic servo has been developed to replace the electro-mechanical servo but, although it is easier to regulate pressure than to regulate the variation of co-efficient friction of a mechanical clutch, it is still not easy to regulate the output torque of the servo within close limits over long periods of time and under extreme variations of temperature as will be experienced at Woomera. Undoubtedly the droning of future aircraft should be easier because they are almost certain to be fitted with automatic pilots anyway, and the safety problems would have been considered in the original design of the aircraft.

9. Instrumentation

Typical instrumentation on a drone will include some device to assist in tracking (a transponder)—in Britain more or less a standard device—telemetry equipment and cameras or some other miss-distance indicator (M.D.I.).

The Firefly and Meteor targets make use of wing tip camera pods. Each pod contains four cameras arranged to give 360° coverage. An additional calibrating camera is carried in the fuselage to enable wing deflections to be determined. A camera system such as this will obviously be able to give very accurate information but, in view of the number of films to be processed and inspected, the analysis of results is obviously protracted.

The W.R.E. in Australia have developed their own camera and this is used in the Canberra. The installation in the Canberra uses a pair of these 180° view cameras mounted back to back in each wing, contained in a special package, viewing above and below the wing respectively. In conjunction with the calibrating mirror on the top of the fuselage these enable fully adequate information to be obtained. The lens of the W.R.E. camera is of interest covering, as it does, over 180°. Fig. 12 shows a picture taken with one of these cameras showing the strange optical effect of the extreme wide angle.

FIGURE 12. A photograph taken with the 180° lens of the W.R.E. Camera.

There are other methods of miss-distance indication using radio or radar principles, but little can be said about these.

Telemetry is considered by experienced drone operators as essential as a means of indicating the essential condition of the aircraft when out of sight. Typical information transmitted includes rate of climb, altitude, air speed, fuel remaining and engine speed. The telemetered information is displayed to the master controller on a number of dials in front of him and enables him to judge the condition of the aircraft and, indeed, to anticipate difficulties and to see that his commands are being obeyed.

10. Problems for the Future

10.1. THE LOW FLYING TARGET

When the target aircraft is flown at low level, the tracking and height keeping problems warrant the use of a special low flying target system to cater for heights below, say, 300 ft. at speeds up to 450-500 knots. Since both the radio link and the plotting by radar are ineffective at low level, except at close range, the overall system of control involves holding the aircraft at some reasonable altitude in "sight" and at the appropriate moment initiating a low level run which, from then on, is carried out automatically. This requires an accurate height-lock system. Visual controllers, when properly sited, may control the aircraft if a fixed direction of approach is not satisfactory. It seems unreasonable to expect a target aircraft to carry out "contour flying"

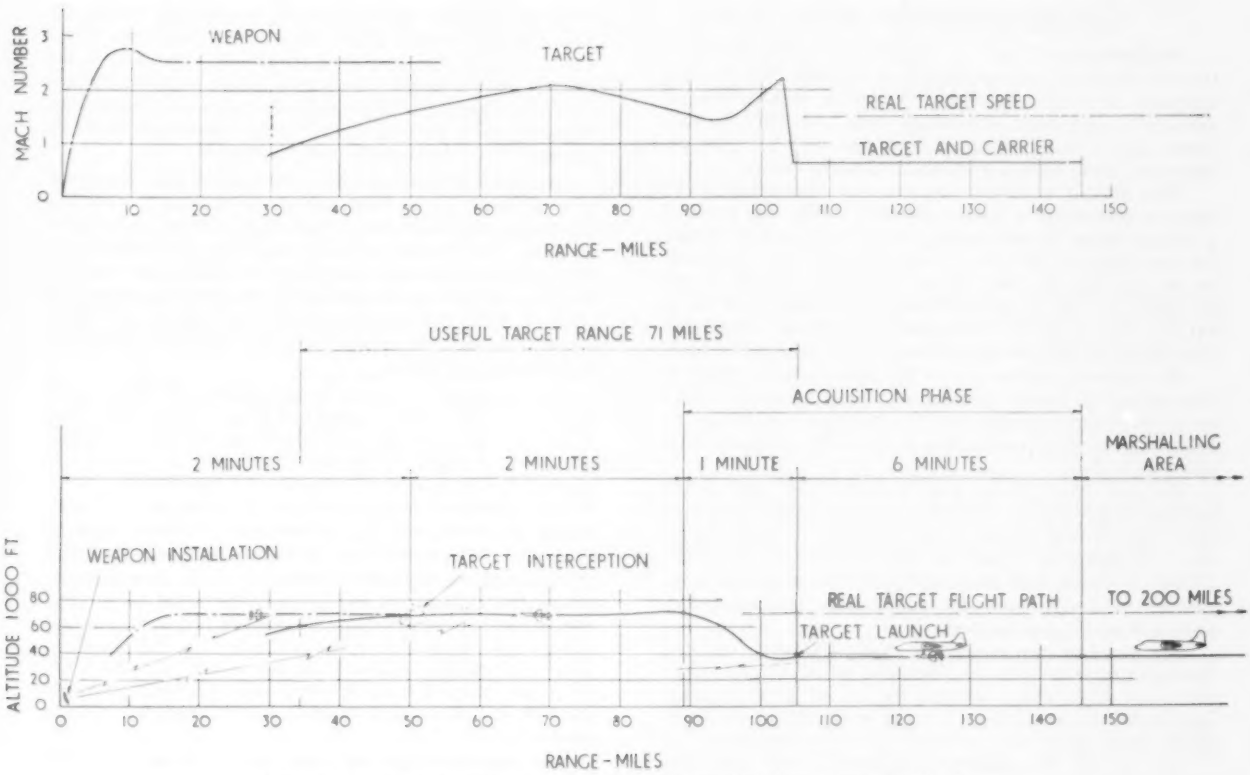

FIGURE 13. The performance of the target, air-launched from about 40,000 ft.

as the degree of manoeuvrability required would be very high indeed.

There would seem to be no technical reason why a low level system of more advanced design should not be developed, although there are obviously certain inherent dangers in having a target flying at high speed and low level over the range where the missile installation is located.

10.2. THE SUPERSONIC TARGET

There is obviously a great shortage of supersonic aircraft in this country and it may be regarded as quite out of the question for a special aircraft to be designed specifically as a target. Thus it seems that there would be little option but to develop some rocket or ram-jet propelled machine similar to the Lockheed Q.5. Fig. 13 illustrates a hypothetical study which has been made for adapting a typical S.A.G.W. Research Test Vehicle to act as a target, carrying it in a bomber and air-launching it at height. This could give speeds approaching $M=2$ and durations well above 60,000 ft. of about 3 minutes when launched from 40,000 ft. There would, of course, be a number of practical difficulties with this scheme. However, the illustration serves to show the sort of performance which could be achieved and the type of target device which may have to be considered.

11. Conclusions

This paper has endeavoured to review the need for target aircraft in relation to the development of anti-aircraft weapon systems. Too often is the target the final item to be thought of. Since expenditure on targets is "unproductive" of anything except the knowledge that a weapon actually works, many people regard it with suspicion.

The techniques of the automatic control of drones are closely related to the automatic flight and landing of military and civil aircraft and much of the experience gained could be applied to more "productive" fields.

The British target service provided by Jindivik, Firefly, Meteor, and Canberra must be supplemented eventually with other aircraft and some sort of supersonic machine. As we are now entering the era of the anti-aircraft guided missile, we will need target aircraft until the development of offensive missiles forces the replacement of target aircraft with target missiles.

ACKNOWLEDGMENTS

The author repeats again that the credit for the development of the British target system rests with the Royal Aircraft Establishment at Farnborough. The successful development of the Canberra 10 has been greatly assisted by help given by Australian engineers and R.A.A.F. officers attached to the author's firm for this purpose, and this is an appropriate opportunity to acknowledge this help publicly.

If the author is its spokesman, such credit for the work on the Canberra 10 as may be due rests with the engineering team at the author's firm.

SUMMARY OF DISCUSSION

Mr. Bateman felt that he would like to tackle Mr. Conway on one point not mentioned in his lecture. Was the best approach to target aircraft to modify an existing piloted aircraft? Australian experience with the Jindivik had shown that a target designed from the start for pilotless operation could have a very good accident record.

Why should a target aircraft incorporate the safety features needed for a piloted aircraft? Why not produce a cheaper target by eliminating all the equipment installed for the safety of the pilot? And was the right approach to use runways for take-off and landing? Would it not be better to use a ground-launching device such as a catapult and to recover the target by parachute. It seemed unnecessary to follow the manoeuvres of manned aircraft.

Mr. Conway replied that in the early stages of Jindivik development a piloted version had been used. It would have been unreasonable for the Canberra U.10 to be shipped to Australia rather than flown out in a conventional way with a pilot.

He felt that there was a place for the larger manned target aircraft as well as for the smaller Jindivik type. It was very difficult to give an idea of their relative cost. It depended largely on the assumed value of the Canberras which were converted; although the R.A.F. considered these were worn out, the Treasury reckoned they were still worth a great deal.

Mr. Bateman then came back to say that he thought the development tests with the Canberra target aircraft could have been made with a manned aircraft; by omitting much equipment the final target version could then have been made much lighter and cheaper if it were unmanned.

Dr. G. W. H. Gardner (Chairman) said that this idea reminded him of a scheme which had been suggested to him. This was that a Chinese copy of an existing aircraft should be built, identical in configuration, but with the cheapest and simplest structure possible. Ballast would replace most of the powerplant weight and rockets would be used for propulsion. This target could be towed to height and the rockets fired to provide an expendable single-mission target.

Mr. Conway said that each Canberra U.10 might be intended to operate for 20 target sorties. A balance had to be held between the cheapness of a target and its reliability; Australian experience showed that the cost of an abortive missile trial was out of all proportion to the cost of a target aircraft. It was worth a slight increase in the cost of the target if its reliability were improved.

Mr. D. Keith-Lucas (Short Bros. and Harland Ltd.) said that the weakness of a converted aircraft was that a target of this type was one or two generations behind the actual enemy aircraft which the missiles under test would attack. Surely the only way to get an up-to-date target was to design one from the start? There were two current cases, the supersonic target and the target for testing anti-ballistic missile missiles. How could this second target be produced?—A conversion was impossible.

Mr. Page (Folland Aircraft Ltd.) asked why up-to-date aircraft could not be taken for use as realistic targets. **Mr. Conway** replied that today most credit seemed to be given to those who created primary weapons; less importance was sometimes attached to making sure that these weapons worked. Almost all the available money was devoted to primary weapons; target aircraft had always played a Cinderella role. No country had yet tested its missiles on realistic aircraft targets.

Mr. Granger (London representative of Radioplane) said that in the United States test firings of the Nike Ajax SAM were made against the small piston-engined Radioplane OQ.19 target. This was done both for practice and because it was good for the morale of the citizens.

The discussion then turned on the reliability and complexity of auto-pilots and instruments. **Messrs. Cape** of Kelvin-Hughes and **Fell** and **Whiteman** of Elliotts put their points of view, while **Dr. Gardner** and **Mr. Conway** suggested that auto-pilots and instruments could be simpler, cheaper and more reliable. **Dr. Gardner** said that expensive complexity was the order of the day and that the trend towards electronic solutions was carried too far. He knew of a case where a mass of electronics had been placed in production to do a task which could be done by a simple mechanism.

Mr. Cape said that the quest for reliability had been lost because instrument manufacturers were asked to produce equipment which had a range of duties. If there were only one function, reliability could be achieved.

Mr. Whiteman said that from the instrument manufacturer's viewpoint reliability, expense and simplicity were inter-related. What production runs of equipment could be expected?

Mr. Conway said he was doubtful if more than 50 of any one auto-pilot would be ordered—and perhaps only 10 for target aircraft. For the smaller types of target the figure might be 100-200.

Dr. Gardner concluded the discussion by thanking Mr. Conway for the kind comments he made about the R.A.E. in his lecture. He hoped that the Canberra U.10 would have the same success rate as other targets; the Jindivik had a life 4-5 times greater than was originally expected.

Air Traffic Control and its Influence on the Navigation Problem*

by

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(English Electric Co. Ltd.)

NAVIGATION used to be solely concerned with the safest and most expedient means of directing an aircraft to its objective—either the destination airport or a military target. Nowadays, especially in civil aviation but increasingly in military transport operations, the need to comply with air traffic control (A.T.C.) procedures is tending to dominate both the technique of navigation and the kind of navigation aids used.

In recent years great stress has been placed on the problem of air traffic control and now, with the imminent arrival of jet air liners in large numbers, the consternation is even greater. Reactions to the problem vary, so that on the one hand there are the down-to-earth realists who see no immediate prospects of any revolutionary improvement in A.T.C. methods; on the other hand there are the optimists who already speak of the present A.T.C. system as though it is a thing of the past and talk of the "new" system which will replace it when the jets arrive. Despite the most extensive studies of the problem, such as that recently undertaken by the Curtis Presidential Committee in the United States, no entirely satisfactory description of the "new" system of A.T.C. has materialised. Meanwhile the penalities of restriction and delay of jet aircraft by air traffic control need no emphasis, but to give one example, the Comet I, when operated by B.O.A.C., regularly arrived at London Airport with at least two hours fuel as diversion and traffic reserve. The weight of this fuel was of a similar order to the total payload of the aeroplane, so it will be realised that economic operation of jet aircraft can stand or fall on this single issue of air traffic control.

This paper is an attempt to give a brief outline of the nature of this difficult problem of air traffic control, to suggest principles of the present system which will probably have to apply to any future system of A.T.C., and to consider the question whether air traffic control will always be the millstone around the neck of aviation it tends to be at present, despite the staunch efforts of the Air Traffic Control service.

The Purpose of A.T.C.

The primary purpose of A.T.C. is to maintain separation between aircraft and to maintain some order in the movement of aircraft. It is true that A.T.C. gives navigational assistance and information to pilots, especially when in distress, and that G.C.A. (Ground Controlled Approach) operators who give navigational assistance during approach to landing are also part of the A.T.C. service, but these are ancillary and not primary functions of A.T.C.

It seems that order must be instituted in the flow of air traffic for even a rudimentary A.T.C. system to work efficiently. Thus we find that even in good visibility aircraft are required to circuit an aerodrome in a methodical way so as to help both the pilots themselves and the controller to maintain separation between them. Order is required to reduce the possibility of conflict to manageable proportions and to enable conflict to be avoided in a systematic way. Thus, if we take ten aircraft flying at random, they might theoretically collide with each other in 45 different ways, assuming only two aircraft were involved in a collision. If, however, we direct these ten aircraft one behind the other along a common path, they could only collide in 9 ways. Thus we have reduced the number of potential conflicts to be examined by a factor of 5. This factor increases with the number of aircraft being controlled, and in this case happens to equal half that number. Apart from reducing the number of ways of colliding, however, the introduction of order simplifies the controller's task. With the random distribution he would have to carry out a number of interception exercises to determine whether collision risks existed. With the aircraft channelised, he need only ensure that longitudinal or vertical separation is maintained between them. This simple fact of the need for order is fundamental in an A.T.C. system above a certain traffic density.

There is, however, a paradox here. Although the introduction of order reduces the number of ways in which a collision can occur, it does not reduce the chance of collision but actually tends to increase it, unless appropriate action is taken. Thus it is true to say that, in maintaining separation between aircraft channelised along airways, the controller is solving a problem partially of his own making.

Need for Planning

The need for planning in A.T.C. systems arises from the need to anticipate conflict and to give the necessary clearances to aircraft before they penetrate the minimum separations from other aircraft which are specified. Planning ahead also facilitates division of the air space between a number of controllers, so dividing the load. It is this planned forward-looking method of control which is the main feature of the present civil A.T.C.

*Based on a Lecture given to the Boscombe Down Branch of the Society on 11th March 1958.

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FIGURE 1. Flight progress boards at the Southern A.T.C. Centre. The white strips are marked with altitude and estimated arrival time of each aircraft over *en-route* navigation facilities symbolised by the black strips. When passing clearances to aircraft the Controller maintains altitude or time separation between them.

system using flight progress boards (Fig. 1). Under this system aircraft are required to report their estimated times of arrival and subsequently their actual arrivals over a number of designated reporting points along their routes defined by navigation faciiities. These reporting points are symbolically displayed to the controllers by designators on the flight progress boards.

Flight progress strips are made out for each aircraft over each of the reporting point designators, and the strips show the time and altitude at which the aircraft will pass each facility. The controllers pass clearances to aircraft in such a way as to maintain altitude or time separation between them over each faciiity. At any instant, therefore, the boards show a complete plan of future aircraft movements arranged in an unconflicting way. Action need only be taken by the controller due to *change* in the plan; for example, a new aircraft entering the system; a request by a pilot for altitude change; or a difference between actual and planned aircraft motion resulting in penetration of the separations. The appearance of flight progress boards, containing many flight progress strips, belies the actual simplicity of the system. The main advantage of displaying traffic in the form of a movement plan is that control action need only be taken to cope with departure from plan and not with every movement of the aircraft themselves. In a sense it is a " rate " system and not a displacement system.

Ad Hoc Systems

It is, of course, possible to separate aircraft on an *ad hoc* basis. Radar control in its simplest form epitomises this *ad hoc* method of separating aircraft, made possible by instantaneous knowledge of their relative positions and good communications. However, a single controller can only handle a limited number of aircraft at once on a radar tube—normally not more than about 5—and when the traffic exceeds this, additional radar controllers are necessary. This necessitates co-ordination between these controllers at points of hand-over between them, and thus a form of planning is necessary. Criticism is levelled at the flight progress board type of display because it is so incompatible with the plan position display on the radar tubes.

Experiments have therefore been made, particularly by the C.A.A.'s (Civil Aeronautics Administration) Terminal Development and Evaluation Centre at Indianapolis, U.S.A., to replace flight progress boards with a horizontal pictorial display whereby designators representing the aircraft, called "shrimp-boats," are moved over a map or even over a reproduced radar P.P.I. (Plan-Position Indicator). Although this kind of display has many advantages, it has not so far been entirely successful. The principal reason for this is that controllers using it find that they are not just concerned with the present positions of aircraft but primarily with possible conflict in the future. Thus they find themselves putting the same kind of information (E.T.A.'s (Estimated Time of Arrival) and altitudes over future reporting points) on the shrimp-boats as that normally displayed on flight progress strips. It then seems better to display the shrimp-boats over the airway intersections and reporting points where conflict will occur, so eventually one tends to return to the conventional flight progress boards which do just that. However, the *ad hoc* type of control straight from a radar tube is satisfactory between defined limits of hand-over within a planned overall flow of traffic.

Thus, radar has found its principal application in sequencing aircraft between one or more inbound gates near an airport (at which aircraft are held, if necessary) and the extended centre line of the runway on final approach. Using radar sequencing over this limited portion of the flight it has been possible to achieve much higher I.F.R. (Instrument Flight Rules) landing rates than in any other way. Again, Outbound Radar Control is used to separate aircraft between take-off and their initial cruising altitudes on their routes. This has virtually resulted in the elimination of departure delays where it is used.

Separations Used by Air Traffic Control

The internationally agreed separation rules used by A.T.C. have grown empirically and are primarily based on the Airways system developed in the United States during the 1930s. The size of the separations depends

on the assumed accuracy of navigation and height-keeping by aircraft, which in turn depends on the navigation facilities used and also on the speed of air/ground communication. When the separations used are compared with the volume of air physically occupied by the aircraft, we begin to see the real cause of "air space saturation," as it is misleadingly called.

Thus in a high density airway, well served with navigation facilities, each aircraft has reserved for it a buffer 1,000 ft. deep, 10 n.m. wide, and 10 minutes cruising speed in length. At a speed of 240 knots this is a volume of 67 cubic miles. That is about 40 million times the volume physically occupied by a Super-Constellation or DC-7 aircraft. Even using radar separation of 5 miles, we are reserving 2½ million times the aircraft's actual volume as a buffer around it. At the other extreme, on the North Atlantic where navigation facilities and communications are poor from the A.T.C. standpoint, we use separations of 120 miles laterally and 30 minutes cruising speed longitudinally, thus, reserving over 1,000 million times the aircraft's volume to each aircraft (Fig. 2).

These enormous ratios need stressing because they show that air space saturation only has meaning in relation to the air traffic control system, and that the term has little validity in relation to the physical situation. Those concerned with air traffic control and its future must always keep this fact very much in mind because it is very easily lost sight of. We see from this that A.T.C. as practised today is a very coarse method of separating aircraft. It is like separating haystacks to ensure that the needles in the haystacks will not touch each other.

Can These Separations be Reduced?

The present separations are empirical and have been adjusted from time to time; notably vertical separation was increased from 500 ft. to 1,000 ft. shortly after the Second World War. A case could be made for undertaking a thorough statistical analysis of navigation errors, variations in ground speed, altimeter errors, and so on, to arrive at a "rational" set of separations which might save air space while giving a more consistent level of safety from collision. However, there are many practical difficulties in this. A.T.C. separation standards have clearly to be agreed internationally, at least in civil aviation. They must make allowance for the fact that standards of navigation vary between aircraft and according to facilities available in different areas of the world. Apart from this there is a natural reluctance on the part of administrations to work in terms of a calculated risk to revise separations downwards because an air collision could then be shown to have been legislated for, in a certain sense. However, limited studies have been made, for example on the accuracy of position reports over fixes using radar, and on the accuracy of aircraft altimeters, especially at high altitude. Moreover the present separations do take some account of variation in facilities; for example, longitudinal separation can be as low as 5 minutes and as high as 30 minutes flying time, ignoring the use of radar.

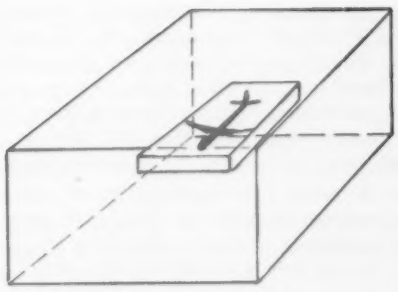

FIGURE 2. North Atlantic A.T.C. "buffer." In separating aircraft on the North Atlantic, the margin allowed for navigation errors and communication delays has the effect of reserving a volume round each aircraft some 1½ million times the occupied air space.

Obviously the number of separation rules must be limited to avoid confusion, and this is another reason for avoiding too many variables in deciding them. While a statistical survey might well yield some reduction in separations, it does not appear that significant savings in air space would follow from this alone.

Separations could be reduced by improved airborne navigation facilities and by more dependable instantaneous communications, especially on long distance flights. At present little use is made of lateral separation between tracks of aircraft flying the same route. It is practically confined to opposite direction traffic crossing each other's altitudes well to the right of the radio range course. On very busy routes like London-Paris and Washington-New York, separate airways are used and these are sometimes confined to one way traffic, which solves the crossing problem. It does not, however, solve the overtaking problem and the incidence of overtaking may increase in future with the wider variation of aircraft speeds due to introduction of jet aircraft. A navigation aid capable of defining parallel tracks safely separated within an airway would undoubtedly help. This is one of the principal reasons for the United Kingdom's advocacy of the Decca Navigator systems which could define such tracks. The use of adjacent tracks does, however, have penalties, especially on long distance routes where navigators may wish to vary track in order to take advantage of pressure pattern techniques to reduce flight time. A wide choice of pre-determined tracks may be offered by such aids as Dectra, but such a route network is bound to be complex and restrictive to a certain extent. On low density routes like the North Atlantic one may well question the justification for confining aircraft to pre-selected tracks throughout the flight in order to avoid what may be considered a negligible chance of the presence of an aircraft on an adjacent track. It is rather like controlling a crossing on a very lonely country road by means of traffic lights.

Longitudinal separation could be reduced by the use of aids giving very accurate indication of distance flown and E.T.A.'s at designated reporting points ahead. Doppler is such an aid and its use on the North Atlantic

might permit reduction of longitudinal separation well below the 30 minutes used at present. It seems likely that most of the big civil jets now on order will eventually be fitted with Doppler and, if they are all so equipped, reduced separation between them might be adopted during cruise since they will then be confined to altitude layers not shared by piston-engined aircraft.

There is room for improvement of the pressure altimeter, and developments in the U.S.A. promise considerable increase in accuracy. However, the altimeter's accuracy is inherently dependent on the vertical pressure gradient, and therefore fails off at high altitude. With the introduction of jets, vertical separation is initially being increased at high altitude. The *EUMED* (European-Mediterranean) regional meeting of I.C.A.O. recommended early in 1958 adoption of 2,000 ft. vertical separation between aircraft flying above 22,000 ft.

We may conclude that a limited reduction in A.T.C. separations may result from general adoption of improved airborne navigation aids, especially a wider application of lateral separation. Such improvement depends on all aircraft in a given air space adopting aids capable of defining the tracks. International agreement on competing systems has proved very difficult since the war, and this is one reason why self-contained airborne aids such as Doppler show such promise. They do not depend on international agreement in the building of ground stations. One can visualise, for example, Doppler, with its associated computer, being used to follow any defined track, including parallel tracks in a wide airway. When within the coverage of ground-based aids such as VOR or Decca, the Doppler could be checked periodically to remove the cross-track errors resulting from errors in the compass. Such a system might be adopted in the upper air route network shortly to be introduced above 20,000 ft. in Europe because most civil jets will already be fitted with the Doppler system for assistance in long range navigation.

Clearly a more immediate means of reducing separation generally in high density areas is by application of ground radar to air traffic control. The problem of using reduced separations permissible with radar *continuously* is one of the most important facing A.T.C. authorities at this time. As already stated, radar is at present extremely useful for maintaining separation between aircraft over a limited portion of their flights within an overall procedural system of traffic flow. It is also extremely useful for lubricating the procedural method of A.T.C. periodically, *e.g.* an aircraft may be handed over to radar control to clear it through the altitude of another aircraft it is overtaking or crossing, after which it would revert to procedural control.

One of the reasons why radar separations cannot yet be used continuously is that dependable cover of ground radars is limited and reversion to normal separations is necessary when aircraft go out of radar cover. The situation may get out of hand if the procedural controller reliquishes his responsibility for separation entirely to the radar controller and then the radar fails, or the aircraft goes out of cover. As this sometimes happens, procedural controllers have been understandably reluctant to release many aircraft to radar control except between the defined limits already mentioned, and thus full advantage cannot be taken of the closer separations permissible with radar in increasing the movement rate. Clearly this will always be true while radar service is discontinuous—while there are large gaps in the effective cover due to unserviceability, interference by rain returns, and so on. Continuity of radar service is such an over-riding requirement that it is influencing the choice of radar design and tending to favour the use of longer wavelengths like 50 cm. with its inherent reliability and immunity from weather returns which mask the aircraft echoes on short wave radars. However, with present manual methods of A.T.C., it seems unlikely that separations as small as the minimum ones permissible with radar can be used throughout flights even if one has continuous radar cover. For example, a buffer must be allowed to avoid continuous action by the controller to prevent minimum separations being penetrated.

There is also the problem of hand-over between one radar controller and another, responsible for an adjacent area. A certain period of time is required for the hand-over and this may be prolonged if the second controller is temporarily occupied with other movements in his area. It is therefore necessary to ensure that separation from other aircraft before hand-over is sufficient to allow for possible deterioration in such separation during the delay of hand-over. This requires some prognosis or planning for the hand-over. A further point is that radar failure or radio communication failure may occur and separations need to be sufficient to ensure that collision does not occur during the period required for implementing appropriate emergency action.

Undoubtedly the greatest improvements in A.T.C. since the war have been mainly due to more effective use of ground radar and we can look forward to further improvement by extension of radar cover and by improved techniques in its use. This is the most promising development at this time, but the efficient combination of radar and planned control still presents many challenging problems to those concerned with A.T.C. development.

Alternatives to Ground Control

Even with radar, separations of the order of 5 miles are used, and radar does not identify the collision case with high definition. As already stated, under conventional A.T.C. procedures a buffer volume is monopolised around each aircraft many million times that of the aircraft itself. Looking to the more distant future, we may not be able to afford the waste of air space involved in these buffer volumes. Mere proximity of aircraft is being treated as a danger in itself, which it is not, except in the very isolated instances when they happen to be on collision courses. It is instructive to consider the efficient use of air space and phenomenally high movement rates which can be achieved in visual conditions when the ability of the pilots to distinguish the collision case is exploited to the full. One recalls the high movement rates achieved at R.A.F. flying

schools. Another example is the rate achieved at a typical rally of private aeroplanes of the kind which takes place at small aerodromes in the United States. Many hundreds of aircraft are landed or taken off in a period of two or three hours. Average movement rates of one aircraft every 20 seconds are achieved over these long periods by "week-end" pilots. Now it is true that these are small, slow speed, manoeuvrable aeroplanes, but when such landing intervals are compared with two or three minutes, which is the best achievement under I.F.R. in transport aeroplanes by current A.T.C. methods, the difference is much more than a matter of aircraft manoeuvrability. If we could give pilots information on nearby aircraft equivalent to that of his visual lookout (and without the limitations of the cockpit's field of view) then we might achieve movement rates in all weather conditions equivalent to the highest now achieved in good visibility. What is being suggested here is a collision warning device as a substitute for A.T.C. separations.

The Air Transport Association (A.T.A.) of the United States airlines has been negotiating with the United States industry regarding the development of a collision warning device, and many possible techniques including radio, radar, infra-red, ultra-violet, heat homing and others, have been investigated. At present this device is primarily conceived by the A.T.A. as a supplement to A.T.C. and not a substitute for it. It is an extremely difficult problem to develop such a device, but if a suitable system is designed it may ultimately be developed to effect a revolutionary improvement in the free movement of air traffic. However, it is assumed that an A.T.C. system would still be required to maintain order in the traffic flow, as otherwise it would be difficult to develop systematic procedures for avoidance of other aircraft, especially in high density areas.

Although the A.T.A. studies are primarily concerned with United States internal operations, the author has always thought that the first and most pressing need for such a device is for use on long distance routes like the North Atlantic where, under present conditions, delay and restriction of movement is necessary due to the A.T.C. system's inability to distinguish the collision case from aircraft being over 100 miles away from each other. Because of navigation errors and communication delays, the separations are so enormous that only once in a thousand million times would aircraft in the same "air space" collide with each other. Thus with a suitable collision warning device there could be practically unrestricted movement and avoiding action would be necessary only on very rare occasions.

Later, such devices might be exploited on higher density routes, and perhaps even in terminal areas. In this way the A.T.C. function may eventually become similar to that of traffic control on the roads, responsible for maintaining order in the air, with the responsibility for avoidance of collision in the hands of pilots. The aeroplane is essentially a vehicle requiring flexibility of movement, and ultimately the system of preventing collisions should permit such flexibility to the maximum extent possible.

If it is possible to develop a suitable collision warning device, one effect will be to avoid the choice of navigation systems being dominated primarily by considerations of traffic control. It must be remembered that most collisions still take place with the ground, and not with other aeroplanes; such accidents are frequently associated with navigation failures in the fundamental sense of failure in aircraft positioning. The higher speed of jet transports will increase the tempo of navigation and place increased demands on the aids employed; furthermore these new aircraft will need to be flown by the optimum route with respect to the wind field in order to avoid fuel and payload penalties. It is such considerations as these, which apply whether the aircraft is on a high or low traffic density route, which may come to influence the choice of navigation aids, although it will probably continue to be necessary to follow an orderly system of departure and arrival routes in the vicinity of airports.

AUTHOR'S NOTE

The opinions expressed in this paper are the author's own; they do not represent the policy of the Company.

TECHNICAL NOTES

The Eddy Diffusivity in Annular Flow

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AN INVESTIGATION into the turbulent flow characteristics in a smooth-walled annulus has been continued. Velocity and its correlation has already been dealt with in the author's note[1] in the November 1958 JOURNAL (p. 830). In the work presented here, the eddy diffusivity in gas flow is discussed, its distribution predicted, and experimental results for the eddy diffusivity of heat in an insulated annulus with a heated inner wall are included in support.

The distributions of velocity, shear, temperature and heat flux for an annular flow with heat transfer at the inner boundary are shown diagrammatically in Fig. 1. The features of the turbulent velocity profile and methods of correlating velocity distribution are outlined in Ref. 1. The shearing stress T is given by the equation

$$T=T_0\left[\frac{r_0}{r}\right]\left[\frac{r_m^2-r^2}{r_0^2-r_m^2}\right] \quad . \quad . \quad . \quad (1)$$

while the local heat flux q may be obtained from

$$q=q_w\left[\frac{r_1}{r_0^2-r_1^2}\right]\left[\frac{r_0^2-r^2}{r}\right] \quad . \quad . \quad (2)$$

which is derived on the assumptions that the local axial temperature gradient $(d\theta/dx)$ is constant across the section and that the velocity is uniform. The latter assumption is not unreasonable in the turbulent zone.

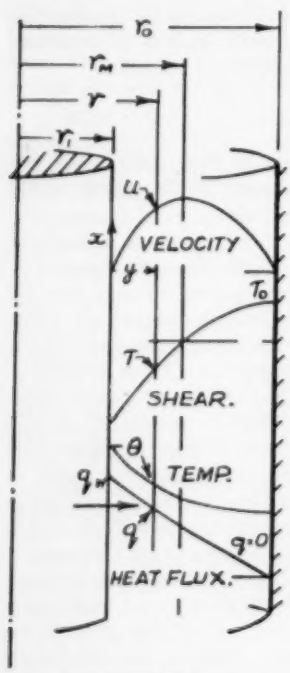

FIGURE 1. Annulus.

THE EDDY DIFFUSIVITY

The eddy diffusivity ε measures the contribution of the turbulent mixing to the transfer processes (momentum and heat), so that in a turbulent flow the equations for local shearing stress and local heat flux are

$$T=\mu\,(du/dy)+\varepsilon_M\rho\,(du/dy)$$

and

$$q=k\,(d\theta/dy)+\varepsilon_H c\rho\,(d\theta/dy)$$

where μ, k, c and ρ are the fluid properties, viscosity, thermal conductivity, specific heat and density. The first term on the right-hand side of these equations measures the molecular action, which in gas flow is small compared with turbulent mixing, so that across the major part of the flow section:—

$$T=\varepsilon_M\rho\left(\frac{du}{dy}\right) \quad . \quad . \quad . \quad (3)$$

and

$$q=\varepsilon_H c\rho\left(\frac{d\theta}{dy}\right) \quad . \quad . \quad . \quad (4)$$

The eddy diffusivity of heat ε_H can be predicted from the shear equation if the variation in $(\varepsilon_H/\varepsilon_M)$ with y is known. Most conveniently $\varepsilon_H=\varepsilon_M\,(=\varepsilon)$, an assumption which is warranted when the fluid is a gas and which implies that the Prandtl mixing lengths for the two transfer processes are equal.

Before dealing with the annulus problem, the eddy diffusivity for an open pipe flow will be determined using equation (3), a procedure which is well known. The friction T varies linearly with radius while the velocity gradient (du/dy) may be determined from the universal logarithmic velocity profile

$$\frac{u}{\sqrt{(T_0/\rho)}}=A+B\log_e\left(\frac{y\sqrt{(T_0/\rho)}\,\rho}{\mu}\right) \quad . \quad (5)$$

where $B=2{\cdot}5$.

On differentiation, this equation gives

$$\left(\frac{du}{dy}\right)=\frac{2{\cdot}5}{y}\sqrt{\left(\frac{T_0}{\rho}\right)}$$

The distribution of ε_M is then determined by substitution in equation (3). However, at the axis of the pipe where the shear is zero, (du/dy) is finite according to equation (5) which makes ε_M zero there. As the eddy diffusivity can only be zero in the absence of turbulent mixing, there is an obvious weakness in this simple analysis. With this in mind, the distribution of eddy diffusivity across the annular spacing may be determined in a similar manner. In this case the shear stress to be used in equation (3) is given by equation (1). For the velocity gradient (du/dy) there are two possible equations of the logarithmic form from which it can be determined. The variations of the universal logarithmic velocity profile are described in the previous note[1]. If the velocity gradient is determined from an equation similar to equation (5) (A and B would be the appropriate constants for the annular velocity distribution), then at $r=r_m$, the radius of maximum velocity (du/dy) will be finite which, with $T=0$, makes ε_M zero there as for the open pipe. The weakness of this procedure is again apparent.

The alternative is to use the modified universal profile of Rothfus, Monrad and Senecal[2]. This is

$$\frac{u}{\sqrt{(T_0/\rho)}}=A+B\log_e\left(\frac{Y_E\sqrt{(T_0/\rho)}\,\rho}{\mu}\right)$$

where A and B have the same values for a pipe and where Y_E is given by

$$Y_E=\left[\frac{r_0^2-r_m^2}{r_0}\right]-\left[\left(\frac{r_0^2-r_m^2}{r_0}\right)^2-r_0^2+r^2+2r_m^2\log_e\left(\frac{r_0}{r}\right)\right]^{\frac{1}{2}}$$

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The velocity gradient then becomes

$$(du/dy)=\frac{2{\cdot}5\sqrt{(T_0/\rho)}\;dY_E}{Y_E\;dy}=\frac{2{\cdot}5\sqrt{(T_0/\rho)}\;dY_E}{Y_E\;dr}$$

since $r=r_1+y$.

At this point, it should be noted that at $r=r_m$, the radius of maximum velocity, this equation predicts (du/dy) to be zero (as dY_E/dr is zero there) and this is correct in reality. With the variation in velocity gradient known, the distribution of ε_M along the radius is determined from equation (3). For comparison with experimental data, it is more convenient to use a non-dimensional eddy diffusivity parameter so that the final form of the equation is

$$\frac{\varepsilon_M}{(r_0-r_1)\sqrt{(T_0/\rho)}}=\frac{1}{2{\cdot}5}\left(\frac{r_0}{r}\right)\left(\frac{r_m^2-r^2}{r_0^2-r_m^2}\right)\frac{Y_E}{(r_0-r_1)}\left(\frac{1}{\frac{dY_E}{dr}}\right) \qquad (6)$$

The friction velocity $\sqrt{(T_0/\rho)}$ which is made with the outer wall shear stress T_0, may be obtained from $f_0=\dfrac{2T_0}{\rho u_0^2}$ with $f_0=0{\cdot}079\ Re_0^{-1/4}$. The Reynolds number Re_0 for friction correlation in the annulus is $Re_0=2\left(\dfrac{r_0^2-r_m^2}{r_0}\right)\dfrac{u_0\rho}{\mu}$.

The derivation of this type of equation is due to Rothfus, Monrad and Senecal and is recorded in the author's paper[3]. Equation (6) is plotted against the fractional wall distance $\left(\dfrac{r-r_1}{r_0-r_1}\right)$ in Fig. 2. The experimental points are for the eddy diffusivity of heat ε_H and are shown for comparison on the understanding that $\varepsilon_H=\varepsilon_M$ as explained previously. These values were determined from

$$\varepsilon_H=\frac{q}{c\rho\,(d\theta/dy)}$$

with equation (2), the wall heat fluxes and temperature gradients being obtained from the results of the heat transfer experiments made by the author[3]. The temperature gradients were determined by graphical differentiation of temperature profiles so that the plotted values can only be considered approximate.

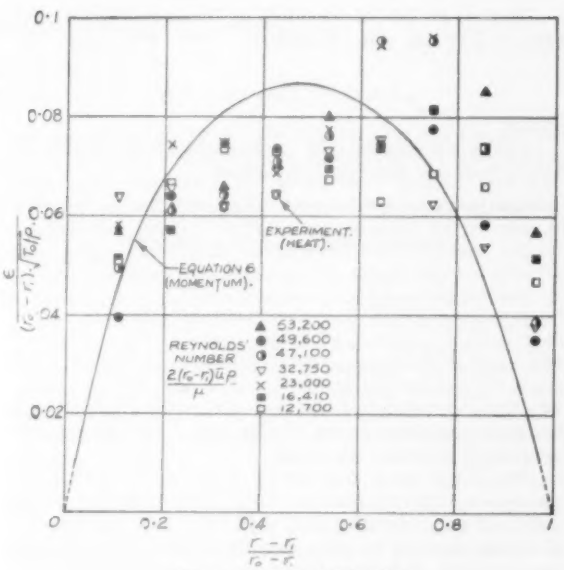

FIGURE 2. Eddy diffusivity.

CONCLUSION

A close examination of the experimental data for eddy diffusivity of heat indicates that maximum values are reached inside and outside the radius of maximum velocity. The distribution is similar to that for an open pipe. While the proposed equation predicts a maximum value at the point of maximum velocity it shows fair agreement with experiment. The present analysis has the distinct advantage that it results in a single equation for the determination of eddy diffusivity across a section with an asymmetrical turbulent velocity profile.

REFERENCES

1. BARROW, H. (1958). Annular Flow—A Note on the Turbulent Velocity Profile. *Journal of the Royal Aeronautical Society*. November 1958.
2. ROTHFUS, R. R., MONRAD, C. C. and SENECAL, V. E. (1950). Velocity Distribution and Fluid Friction in Smooth Concentric Annuli. *Industrial Engineering Chemistry*, Vol. 42(2), p. 2511, 1950.
3. BARROW, H. (1955). Fluid Flow and Heat Transfer in an Annulus with a Heated Core Tube. *Proc. of the Institution of Mechanical Engineers*, Vol. 169, p. 1,113, 1955.

Exact Results for the Bending Shear Stress Distribution for Some Simple Sections

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THE NUMBER OF available exact solutions to the St. Venant flexure problem is limited, but there are some simple solutions which appear to have been overlooked. The sections covered are a wedge, a double wedge, a biconvex section, and an aerofoil-type section. All the solutions given are restricted to certain values of Poisson's ratio, depending on the section.

CONDITIONS TO BE SATISFIED

The components of shear stress parallel and perpendicular to the direction of loading are given by:

$$q_y=\frac{\partial\phi}{\partial x}-\frac{Py^2}{2I}+f(x) \quad . \quad . \quad . \quad (1)$$

$$q_x=-\frac{\partial\phi}{\partial y} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where P is the shear force and I the moment of inertia of the cross-section about its neutral axis.

ϕ is a stress function satisfying

$$\frac{\partial^2\phi}{\partial x^2}+\frac{\partial^2\phi}{\partial y^2}=\frac{\nu}{1+\nu}\frac{P}{I}(x-c)-\frac{df}{dx} \quad . \quad . \quad (3)$$

and $f(x)$ is chosen to make $f(x)=Py^2/2I$ at the boundary of the section, making $\phi=0$ at the boundary. c is the x co-ordinate of the centroid of the section.

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There is no loss of generality in taking $P/I=1$, so that $f(x)=1/2\,y^2$ at the boundary. We will also use

$$\nu'=\frac{\nu}{1+\nu}.$$

WEDGE

This is the simplest type of unsymmetrical section, for which there are few results available.

For the section given by $y=\pm hx$, $x=3/2$

$$\phi=a\,(y^2-h^2x^2)\,(x-3/2) \text{ satisfies (3)}$$

if $$a=\frac{h^2}{1+3h^2}$$

and $$\nu'=\frac{3h^2\,(1-h^2)}{1+3h^2}.$$

The shear centre is at $4/5\,(1-a)$ of the chord length from the apex, agreeing with the Griffith and Taylor thin-section approximation, when h is small.

The shear stress distribution is parabolic both along the sides and the base of the triangle, the maximum values being $9/8ah\sqrt{(1+h^2)}$ and $9/8h^2\,(1-2a)$ respectively. The latter figure is the maximum for the section as a whole, equal to $3\,(1-2a)$ times the mean, if $a<1/4$ or $h^2<1$; since a is small, of the order h^2, the stress on the side of the wedge is small in this case for a thin section.

DOUBLE WEDGE

For

$$\left.\begin{aligned} y^2&=h^2\,(1+x)^2 && x<0\\ y^2&=h^2\,(1-x)^2 && x>0 \end{aligned}\right\}$$

$$\left.\begin{aligned} \phi&=\frac{1}{4}x\,[y^2-h^2\,(1+x)^2] && x<0\\ \phi&=\frac{1}{4}x\,[y^2-h^2\,(1+x)^2] && x>0 \end{aligned}\right\}$$

provided that $$\nu'=\frac{1}{2}\,(1-h^2).$$

The stresses are

$$q_y=\frac{1}{4}h^2\,(1-x^2)-\frac{1}{4}\,y^2$$

$$q_x=-\frac{1}{2}xy.$$

The maximum stresses are $1/4\,h^2$ at the mid-point of the section and $1/8\,h\sqrt{(1+h^2)}$ at the middle of the sloping surface. This is now large in comparison with the stress at the neutral axis, for a thin section, being of order P/t^2 where t is the section thickness.

The solution given satisfies the boundary conditions for each half of the double wedge (separated by $x=0$) separately, but each single wedge is subjected to torsion as well as bending. The known thin-section torsional rigidity can be used to derive a shear centre, $\left(\frac{14}{15}-\frac{1}{3}h^2\right)$ from the apex, in agreement with the Duncan thin-section approximation, when h is small. The corrected surface stress of the single wedge is $\frac{1}{24}\,h\sqrt{(1+h^2)}$.

BICONVEX SECTION

$$y^2=h^2\,(1-x^2)^2$$

$$\phi=\frac{x}{10}\,\{y^2-h^2\,(1-x^2)^2\}$$

provided that $$\nu'=\frac{1}{5}(1-4h^2).$$

The stress distribution along the axis ($y=0$) is

$$q_y=2/5\,h^2\,(1-x^2)$$

The peak stress ($2/5\,h^2$) is $7/4$ times the mean stress on the section. The stress distribution along the surface is given by

$$\frac{1}{5}xy\sqrt{(1+4h^2x^2)}$$

and its maximum value is nearly $\frac{2}{15}\,h\sqrt{3}$ at $x=1/\sqrt{3}$

approximately. This exceeds the maximum stress at the neutral axis if h is small, as for the double wedge.

AEROFOIL-TYPE SECTION*

$$y^2=h^2x^2\,(1-x)$$

$$\phi=\left(\frac{1}{8}x+b\right)\,\{y^2-h^2x^2\,(1-x)\}$$

where $$b=\frac{-\frac{1}{14}\,(1+h^2)}{1+\frac{5}{7}h^2}$$

provided that $$\nu'=\frac{\frac{1}{4}\,(1-h^4)}{1+\frac{5}{7}\,h^2}.$$

The shear centre for a thin section at 0·636 chord from the trailing edge ($x=0$) agrees with the Duncan approximation.

The maximum shear stress at the neutral axis is $\frac{2}{35}\,h^2$, equal to 1·65 times the mean stress. However the maximum stress on a thin section occurs at the surface, at about 0·15 chord from the leading edge, and has the value $0{\cdot}023h$. The same remarks as regards relative order of magnitude of the two stresses apply as for the two previous sections.

CONCLUSIONS

Summing up the results presented, the respective thin-section approximations to the shear centre of Griffith and Taylor (for ν small) and of Duncan (finite ν) are confirmed by the exact solutions. The maximum shear stress at the neutral axis ranges from 1·5 to 1·75 times the mean stress on the section. However for a thin section this is not the maximum stress for the section as a whole; this occurs at the surface of the section and is of the order of magnitude P/t^2 where t is the thickness of the section. Comparison of the results for the wedge section (ν small) with the other results makes it clear that this high surface stress is a lateral-contraction (Poisson's ratio) effect, associated with the varying anti-clastic curvature of the beam, which can be seen to cause local twisting.

*This result was given incorrectly by Sistino, *Journal of the Aeronautical Sciences*, p. 402, June 1958.

The Third Agricultural Aviation Research Conference

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THE FIRST of these conferences was held in 1953, the second in 1954 and the third in November 1958 at Milwaukee. This third conference was sponsored by the Agricultural Research Service of the United States Department of Agriculture and, to promote worthwhile discussions, attendance was by invitation only.

Twenty papers were presented on four main themes, economics, progress as regards agricultural applications, progress as regards forest applications and, finally, a review of present and proposed research.

It was apparent that during the past two or three years there has been a decrease in the rate of expansion of the industry in the United States. Considerable interest was shown in a paper by an economist who had spent a year in New Zealand; although between 50 and 60 million acres per annum in the U.S.A. are treated in one way or another by means of aircraft, this represents only about 3 per cent of the total area, whereas the equivalent figure for New Zealand is roughly 10 per cent. It was felt that aerial methods of range improvement were probably more advanced in Europe and New Zealand than in the United States, although the proportion of total aircraft time spent in fertiliser application in the U.S.A. had risen to 5 per cent by 1957. Nevertheless, 7 million acres were treated by agricultural aircraft each year in California and this State was said to do roughly one third of all the pest control activities in the U.S.A. and to have one fourth of the aircraft. Furthermore in 1958 there were more than 5,000 aircraft and 4,000 pilots fully engaged in agricultural operations in the United States, the average flying hours per annum per aircraft being 250.

The major reasons for the "levelling-off" or reduced rate of expansion of the agricultural aviation business in the United States seemed to be three in number. Firstly, more progress has been made in the design of ground application machinery for agricultural chemicals in spray form than in the case of aircraft equipment, with the result that competition from ground machinery has increased. Secondly, the introduction of a large variety of agricultural chemicals has given rise to the need for extensive testing to determine the most effective chemicals and the best rate of application for each particular circumstance. Test work of this nature is difficult with aircraft because of the large size of experimental plots required, the problem of separating these plots and the large total area which is necessary if a statistically sound number of replications and randomisations are to be used. Thirdly, the economics of aerial application (including contract operations) has received insufficient attention and the advantages over ground machinery in this respect are not always clear-cut.

A fourth point may well be the number of accidents. A total of 370 accidents occurred in 1957: 26 per cent were found to have been due to stalling and 26 per cent were due to collision with an object; in the latter case, at least 11 per cent of pilots were unaware that an obstruction was in front of them. It was felt that a large number of these accidents were due either to reckless operation or to inadequate flying competence and some attention was given to the possible use of stall-warning indicators. It was pointed out that in the United States an over-load is permitted, whereas in New Zealand, for example, an agricultural aircraft is not treated as being in a different category to a passenger aircraft. There was also discussion as regards centre of gravity limits and it was pointed out by a representative of the C.A.A. that this organisation has only 380 inspectors to cover the "general aviation" category of aircraft in the whole United States and that agricultural aircraft formed approximately 14 per cent of this category, flying more than 800,000 hours per annum. It was felt that twin-engined aircraft should be used for spraying over congested areas and new regulations are being introduced, particularly as regards "stay-up-ability."

Two very interesting papers were presented on helicopter developments for agricultural uses and a discussion ensued on the need to design agricultural aircraft for world markets, rather than for one country alone.

In contrast to the apparent steady state of agricultural aviation in the U.S.A., it was shown that appreciable progress has been made in the use of aircraft for forest applications. Two papers were presented on fire fighting, both as regards transporting personnel or laying hoses etc. by helicopters, and the cascading of fire retardants or extinguishers into the heart of a forest fire from fixed-wing aircraft. Most of the development work has been done in Western sections of the United States and considerable success was achieved in 1957; however, the number of fatalities in the operation of these so-called "air tankers" has been high and the United States Forest Service is now only employing pilots with a minimum of 1,000 hours experience and is enforcing a minimum height of 75 ft.

Other research reports which were presented dealt with corrosion, insecticide dispersal apparatus, ram-air type distributors for seeds and fertilisers, measurement of spray deposit patterns, the use of propelled models for research into aerial application problems, meteorology near the ground, and spraying equipment. Some of the points on which further research was thought to be urgently desirable were as follows. Firstly, fundamental information on droplet size formation, particularly in the case of emulsions, and of rates of evaporation during descent. Secondly, basic data on the relationship between wind speed, particle size and drift. Thirdly, an all-embracing demand for fundamental information on the relationship between ground coverage and volume emitted, with the various equipment which is available and contemplated. Fourthly, research and development to permit aircraft operation at higher altitudes over rough topography. Fifthly, more data on the economics of operating aircraft for agricultural purposes and better facilities for imparting technical information to commercial operators. It was felt that the amount of research was insufficient at the present time and that greater efforts and finances were needed; the use of models, as suggested in the paper from Canada, might well be of assistance.

There was considerable discussion at the end of the conference on a suggestion that a Pan-American Agricultural Aviation Centre should be set up. This was thought to be desirable, not only because of the need to design agricultural aircraft and equipment for operations in a number of different countries (the American industry has until now paid little attention to this point), but also to create an organistaion which could co-operate with the European centre and ultimately promote world-wide co-operation. A growing and lively interest in the agricultural aviation activities of other countries was a particularly noticeable feature of this American conference.

Graduates' and Students' Section

VAUXHALL VISIT

On Wednesday 21st January we visited the car plant at Luton, where Victor, Velox and Cresta models are manufactured. We started with the engine and transmission shop. This vast building, one third of a mile long, was first erected in Canada and later dismantled and shipped to England.

Since the motor industry is essentially concerned with mass production there is ample opportunity for the employment of modern techniques in automation. Vauxhall's, for example, depend entirely on automatic processes for the machining of both the 4 and 6 cylinder engine blocks. This is carried out on a line of 17 machines comprising 110 automatic transfer stations which together complete 565 precision operations. Only 14 men are required to operate this section, which cost £2½ million and can produce up to 78 blocks per hour. Gear boxes are also manufactured by similar means. The 53 station transfer machine used incorporates sets of inspection probes which automatically check that the holes drilled are accurate. After assembly each gear box is tested on a machine which enables it to be run at equivalent speeds of up to 80 m.p.h. To ensure that the syncro-mesh is working properly and that all nuts are tight, gear changes both with and without the clutch, are made at various speeds. Then each gear box is passed onto a continuous belt, which traverses the building, until it is required for attachment to the engine.

The remainder of the building is occupied by the assembly lines for front and rear axles, and for the engine and transmission. Each cylinder bore is measured with an expanding probe and, according to a colour code, a piston with the correct limits is selected. In this way close tolerances can be obtained although both piston and cylinder are mass produced. When the engine is practically complete it is driven electrically at idling speed for 30 minutes while adjustment is made to tappet clearances and warm oil is pumped through to remove any particles of metal or foreign matter.

After completion the assembled engines and axles are transferred, by an overhead conveyor belt, across a 400 foot bridge linking the two main buildings, before reaching the final assembly line, with which the conveyor system is synchronised.

Ever since 1903, and the first Vauxhall, a 5 h.p. single cylinder car, they have always made their own bodies. In the two hours between lunch and tea we visited the new car production building. In the almost entirely automatic plating plant the components pass through many baths, some boiling, some cold before receiving first a copper, then a nickel and finally a chromium layer. Almost a quarter of the floor space is occupied by the vast Press Shop; there are over 220 presses, some of which exert pressures of up to 1500 tons, and the whole is an impressive picture in heavy engineering. Practically all the presses are British-made.

Vauxhall Motors have pioneered several body-assembly techniques which have now become standard practice in the British motor industry. The most important of these are integral all-steel construction and multi-spot welding. A system of side-frame assembly is used which involves locking together the sides, front and rear ends and roof in jigs and progressively welding them into one solid structure as they move along the line.

On completion the body shell moves to the paint shop along part of the 12 miles of conveyor belt. Spraying is carried out automatically, the nozzles following the body contours by means of a "magic eye." After baking the body is completed by adding the windscreen and windows. Stringent tests are applied to the body, one of the most interesting of which is the water test. To check that the body is leak proof it is passed through a tunnel in which intense jets of water are directed at it. An inspector inside plugs all the leaks.

The first stage of the final assembly is carried out on two different floors: on the ground floor the engine and transmission components are aligned, while above, the corresponding body, complete with furnishings and electrical fittings is conveyed at exactly the same speed until, at the right moment, it is lowered on to the engine. Both 4-cylinder and 6-cylinder cars are produced on the same line at the rate of one completed vehicle every two minutes.

Each car is started while still on the line and is driven off the end under its own power. Finally the headlamps are adjusted and the front wheel alignment checked before the car is driven on to free running rollers. The rear wheels are then driven by the engine while the inspector is able to check the transmission, gears, electrical systems and instruments.

The party were impressed by the general efficiency and modern production techniques. Our guides showed great hospitality and readily answered our questions.—J. G. and B. T.

Section Representatives

This list shows the current Section representatives. We would welcome further volunteers and aim to have a committee member of representative in each of the main centres of the industry.

Mr. J. Coplin, Dept. 61, Rolls-Royce, Elton Road, Derby. Rolls-Royce, Derby.

Mr. E. N. Davies, Toc H Hostel, High Street, Swindon. Vickers-Armstrongs (Aircraft) Ltd., South Marston.

Mr. H. Frazer-Mitchell, 59 Cambridge Road, Kingston-on-Thames, Surrey. Handley Page Ltd.

Mr. M. J. Goodyear, D.C.Ae., 16 Brighton Street, Stoke, Coventry. Armstrong Siddeley.

Mr. A. N. Gobby, B.Sc.(Eng.), 90 Elmwood Crescent, Luton, Beds.

Mr. G. H. K. Goold, 27 Clunies Road, Moss Park, Glasgow W.2.

Mr. J. Green, 12 Grange Avenue, Levenshulme, Manchester 19. A. V. Roe, Woodford.

Mr. D. Lennard, c/o Royal Naval College, Greenwich, S.E.10. Royal Naval College.

Mr. V. Morples, c/o Engineering Laboratories, 19 Parkes Road, Oxford. Engineering Laboratories.

Mr. W. McCaffrey, 88 Bidston Avenue, Claughton, Birkenhead. Napier Ltd., Liverpool.

Visit to R.A.E., Bedford

There are still a few vacancies left for the visit to R.A.E. at Bedford on 15th April. Those interested should write to the Hon. Visits Secretary, A. R. M. Pickering, "Riverside," Vicarage Walk, Bray, Berks.

Future Lectures

On Wednesday 25th March Wg. Cdr. J. Jewell of the Martin-Baker Aircraft Co. Ltd., will talk to us on "Aircraft Escape Techniques." This company has pioneered the ejector seat and the development of this technique makes a fascinating story.

On Wednesday 8th April a member of the U.S. Air Attaché's office will speak on "The American Aircraft Industry."

Visit to Paris Aero Show

The price of the visit to Paris for the Paris Aero Show has now been fixed. It includes city centre to city centre transport from London with air journey from Southend to Paris, and two nights bed and breakfast accommodation in Paris (including tax). Departure will be 7 p.m. Friday 19th June, and return 7 p.m. Sunday night 21st June. Inclusive cost is only 10 gns., and as there are only 36 places to be filled, early application is advised, to Mr. J. R. Cownie, 40 Sherwood Avenue, Marshalswick, St. Albans, Herts, enclosing £2 deposit.

Part of the Vauxhall assembly line at Luton.

THE LIBRARY

Reviews

C.F.S. BIRTHPLACE OF AIR POWER. *John W. R. Taylor. Putnam, London, 1958. 198 pp. Illustrated. 2 Appendices. Index. 21s.*

John Taylor must have put a lot of time into the collection and collation of facts about the Central Flying School before he began to write this account of the R.A.F.'s oldest and most famous (and perhaps best loved) of institutions.

His readers ought to appreciate what he has done for their information and, by anecdote, for their amusement, too. He has captured the spirit of the place, its gaiety, its *esprit de corps*, its tremendously high standard, its honesty of assessment of pilots, its world leadership in the art and practice of instructional aircraft pilotage. Perhaps the emphasis is almost always from the staff side of the school; it would have added to the overall interest of the narrative to have learned something more of the emotions within the pupils' hearts: to have become better acquainted with the work of the men who maintained the aircraft. But perhaps that would have made the book too large and costly.

I found few gaps in the tale as told: no mention of the division of the school into tractor and pusher squadrons in 1916-17, nor of the happy atmosphere in 1920-21 and the excellent jazzband in the officers' mess with Teddy Gerard (who was later killed by a kick from a polo pony in Iraq) handling the drums with skill.

"Mary" Coningham, Chris Draper, "Pedro" Mann and others of that calibre were pilots there then. I recall aerobating with Coningham in a dual Snipe: he was a Flight Lieutenant. But perhaps Pedro—so-called because of his sallow complexion and thin black moustache giving him a supposedly Hispano-Mexican appearance—was even then regarded as the star turn in aerobatics.

I think there are no other gaps and to say that is to say much. Here is the story of how the Central Flying School of the joint Army-Navy Royal Flying Corps of 1912 fared throughout 36 years of peace and 10 of major war. In each of the two world war periods its character was altered to suit the most pressing need of the time, the swift training of pilots. Even so, pupils regarded their posting to Upavon as of more than ordinary significance, demanding from them a higher all-round standard than might be required of them elsewhere. The lazy tried to dodge the fame of gospelled Upavon. Others, like Douglas Bader, gloried in it.

The shot-in-the-arm injected by Smith-Barry's Special School of Flying at Gosport (in 1917-18) resulted in a new post-first-world-war C.F.S. Lord Trenchard's genius was to put the R.A.F. first. So he took all that Smith-Barry had created in the S.S.F. and used it to regenerate the C.F.S. Instead of a pre-war central school for converting R.Ae.C.-certificated army and navy pilots to military flying duties it became the post-war specialist school for the training of flying instructors, which was the essence of the Smith-Barry system. So it has remained almost ever since, except for two years during the Second World War when, superseded by the Empire C.F.S., it became one among the many standard Flying Instructors' Schools.

Throughout all its moves, from Upavon to Wittering, back to Upavon, to Hullavington (as E.C.F.S.) then to Little Rissington as post-Second-World-War C.F.S., the initial spirit which pervaded the school in 1912 under its first commandant, Captain Godfrey Paine of the R.N., has remained, a traditional continuum of excellence in deportment in the air and on the ground. By the attachment to its courses of officers from Commonwealth and foreign Air Forces it spread its own aura of exceptional flying far and wide. This surely must have been a hidden asset in the success of the British aircraft industry in selling its products overseas.

It was also the task of C.F.S. to produce pilot's notes for the handling of new types of aircraft introduced into the R.A.F. (now the duty of the Handling Squadron at Boscombe Down) and to send examiners to tour all R.A.F. flying training schools at home and abroad to ensure that the standards it had set were maintained in practice. These duties were an extension of the handling-and-patter book of the S.S.F. and of the wing-examining officer system that grew out of Smith-Barry's school.

One's only regret in laying down this well-told tale of the C.F.S. is that Smith-Barry never received his due for all he did. An A.F.C. seems a small reward. Trenchard's rule of putting the R.A.F. first denied individual genius to flourish, but gave ultimate credit, through the R.A.F., to the leader of the Service and to its successive leaders. That rule is ancient, many millennia old. It is the law of organised society which rejects the right of an individual to secede from the organisation. To uphold that rule the American civil war was fought. It was on that rule that Trenchard built the R.A.F. and more than one individual left it. This story of the C.F.S. is valuable to the youth of today because it focuses attention on the working of that rule in the careers of R.A.F. pilots throughout 4½ decades, from the era of boxkites to the epoch of jets, as a glance at the multi-star air marshals named in the index will happily confirm.—NORMAN MACMILLAN.

SWITCHING CIRCUITS WITH COMPUTER APPLICATIONS. *Watts S. Humphrey. McGraw-Hill, London, 1958. 257 pp. Illustrated. 66s.*

To quote from the preface "This book is intended both as a graduate engineering text and as an aid to the practising design engineer." To a large extent this aim has been attained.

The book starts by introducing the binary scale and then discusses the simpler aspects of Boolean algebra. The next chapter describes relays and the simple circuits which can be formed from them. The chapter on codes is useful and clear but contains less information than is desirable. The minimising aids described in chapter 5 are of the chart and map variety and the other methods such as McClusky's are not described. Forms of transister and diode logic are treated too briefly in view of their importance and generality. Boolean Matrices are discussed at some length and their application in representing complicated circuits is treated in detail. This chapter one feels is intended for the classroom rather than the design engineer.

The last two chapters are titled "Cascaded Networks" and "Sequential Circuits." The former is a description of circuit elements and how they can be built into large networks of logical elements. The last chapter describes the way in which circuits are designed to do sequences of operations and allows that experience and intuition can be aided but little by systematic procedures.

On the whole the book is well written and should be more of assistance to students than aid to the designing engineer, although he will find quite a number of useful notions.—D. J. WHEELER.

INSTRUMENT FLYING (6th Revised Edition). *P. V. H. Weems and C. A. Zweng. Waverly Press, Baltimore, 1958. 298 pp., Illustrated. 6 dollars.*

The authors offer this as a textbook for students and instructors concerned with the C.A.A. Instrument Rating. The first edition was published in 1931; and it is soon apparent that old ideas are dying very hard. The value of the instrument flying instruction given in this book can be judged from the following statement on page 41:—

"The 1-2-3 system must be followed carefully and each instrument controlled as follows:—

1. Rudder controls the turn indicator
2. Ailerons control the ball
3. Elevators control the airspeed, and the throttle controls the sensitive altimeter."

By modern standards this is heresy! The system was barely feasible with "cloth airplanes" of pre-war weave! The authors grudgingly admit that the U.S.A.F. and Navy nowadays teach Attitude-Flying: as in visual flight, the pilot controls his plane by thinking of its attitude rather than by a mechanical reference of certain controls to certain instruments. The chapter on Instrument Training ends with an unhappy marriage between the two systems; and the authors still fail to recognise that the principles of Attitude-Flying apply equally well to limited-panel conditions (where, without the direct indications of the artificial horizon, the pilot has to translate instrument readings into terms of attitude).

Although this book cannot be recommended to the student of I/F technique, it gives an interesting survey of the radio aids, weather and A.T.C. services in America, as well as an insight into the C.A.A. Instrument Rating System.—B. E. E. MARSHALL.

AMERICAN ACES OF WORLD WAR II. *Edward H. Sims. Macdonald, London, 1958. 318 pp. Illustrated. 18s.*

This book is written by an experienced journalist who himself served in the United States Army Air Force as a fighter pilot and who took part in thirty-three sorties over Germany. With such a background he is very well qualified to write about America's highest-scoring fighter pilots. He has chosen twelve of the highest scoring "aces" now living and has described one of the most exciting operations of each of them.

He has almost achieved the impossible, namely a credible account of an air battle without over-dramatising it. The stories are told very well indeed but they are just a little laboured in cases where the pursuit of an enemy fighter lasts for two or three pages. One tires rather easily of aircraft endlessly "slicing through the sky" but it must be remembered that the author is an American and uses the idiom of the New World very freely. English readers will appreciate the fact that the spelling is very English, however.

The stories cover the Far Eastern as well as the European theatres of operations, and very great credit is due to the author for his technical accuracy as regards the handling of aircraft, operational techniques and other matters of fact. What is disappointing, however, is the inaccuracy which permits the 4th Fighter Group to be the top scoring unit on page 102 and the 56th Fighter Group to take the honours on page 150. Again, on page 130 a Lightning fighter is described as "green-grey" while two pages later it is silver. Little points perhaps but just enough to spoil an otherwise interesting, convincing and accurate, if highly coloured, account of aerial warfare as practised by twelve of America's greatest exponents in the Second World War.—A.S.C.L.

THE AIR FORCES OF THE WORLD. *William Green and John Fricker. Macdonald, London. 336 pp. 60s.*

The sheer volume of information contained in this book is difficult to appreciate even when one realises that it contains a comprehensive history of *every* air force in the world, in addition to creditably complete information about their current organisation, facilities and equipment. There are photographs of many of the aircraft in service and maps showing the more important bases. All this is contained in one volume of 336 large demy quarto pages (11½ in. x 9 in.).

This reviewer's initial reaction was that this was altogether too good to be true! However, more detailed study of the contents shows that the authors have achieved a remarkable standard of completeness. They seem, quite genuinely, to have achieved what they set out to do, even with the Iron Curtain air forces and with such obscure services as the Royal Saudi Air Force, the Laotian Army Aviation Service, the Haitian Air Corps, the Salvadorean Air Force and the Honduran Military Air Arm. In all, the air forces and military and naval air arms of some 82 countries are described. There are over 500 photographs, 77 maps and nine pages of insignia drawings in colour.

The only serious criticism which can be advanced is of its arrangement. The present format is suitable for the general reader and for the student of military aviation who wants a broad picture of the way in which the world's military air services have evolved. A book of this type has its greatest value, however, as a reference and for this purpose the present layout is far from ideal. It would have been preferable if only the purely historical treatment had been dealt with in the descriptive text. Tabulation is used to show the current equipment of each air force but this technique should have been extended to the descriptions of current organisations and facilities. This would be much more effective for quick reference and would avoid the laborious searching through pages of text which is at present necessary to unearth the vital basic information which will most frequently be required by the students, writers and serving officers who use this book.

No doubt revised editions will be required in due course. The authors should see if they can improve their presentation of the voluminous data which they have so effectively collected to make it more readily available for quick reference. A standardised presentation will, of course, highlight the inconsistencies and reveal such gaps as exist in the information provided but this should be accepted. The serious reader would far rather know at once that the particular item of information he is after is not available than only be able to establish this after a lengthy search through a great deal of descriptive matter irrelevant to his immediate purpose.—PETER W. BROOKS.

TRANSFORM METHOD IN LINEAR SYSTEM ANALYSIS. *J. A. Aseltine. McGraw-Hill, London, 1958. 300 pp. Illustrated. Appendices. 66s.*

Besides being a lecturer at the University of California, Los Angeles, the author has had considerable industrial experience of system analysis and is at present a member of the Technical Staff of the Space Technology Laboratories. He has drawn the material for the book from this experience and more particularly from the graduate engineering courses given at U.C.L.A. The result is an excellent engineers' guide to the use of integral transforms.

The first half of the book is devoted to the Laplace transform with application to electrical network and mechanical system problems. Two chapters are given to the derivation and use of frequency response, root locus

and Nyquist methods in linear feedback system analysis and a further chapter considers the Laplace transform solution of partial differential equations. There follow two chapters on Fourier analysis, two on the statistical description of random signals, one on the Z-transform solution of difference equations, and one on Mallin transforms. A short but useful list of Laplace transforms is given in an appendix and a second appendix deals with complex variable theory in order to prove Laplace inversion, complex convolution and Z-transform inversion formulae. The book is written in textbook fashion with problems set at the end of each chapter.

This is definitely a book for engineering students and the author is careful not to frighten away the reader with too much pure mathematics. He uses Laplace transforms to solve a few simple differential equations in chapter one and leaves until chapter two the consideration of the convergence of the integral. This does not mean that the necessary conditions for the use of transforms are omitted; in fact he often illustrates their necessity by well chosen examples. The reader is frequently referred to other publications for formal proofs and here, instead, he is given intuitively convincing, though perhaps not mathematically rigorous, forms of proof.

Criticisms are few and of a minor nature. For instance, it is a pity that the author did not find space to give one or two simple methods of polynomial factorisation when discussing partial fractions with regard to inverse Laplace transformation. On the other hand, he does include references to publications which give such methods.

This is a book which can be recommended to engineering students of graduate level.—A. P. ROBERTS.

APPLIED MECHANICS. *J. A. Cormack. Chatto and Windus, London, 1959. 342 pp. Illustrated. 42s.*

This in an elementary textbook, written "for students who are reading Applied Mechanics at the S.3 stage for the Ordinary National Certificate and for those preparing for one of the professional examinations in this subject." A knowledge of elementary calculus (including simple integration) is assumed.

On the whole, the material is well set out and clearly presented, with a number of worked examples in the text. There are examples at the end of each chapter (many of these being taken from recent papers of the professional societies) and answers are given.

There are, however, one or two points which could be explained more clearly. The slug is mentioned on p. 4, but thereafter the author seems rather shy about referring to this useful animal. This is regrettable inasmuch as this is a book for practical engineers. The use of lb. mass and lb. wt. is very confusing for beginners. Simpson's rule is given without proof. Possibly the readers know the proof, but this is not worth risking. The section on scalar and vector products deserves at least one practical worked example.

In the treatment of the kinetic energy of combined translation and rotation it should be clearly stated that the kinetic energy of a rigid body is the sum of the kinetic energy due to the motion of the *centre of gravity* and that due to motion about this point. The example in this section is only correct under certain conditions.

There are misprints on p. 229 (Wg instead of W/g) and on p. 230 (a square root sign missing), while, in the chapter on hydrostatic pressure, w is called "the weight of liquid in lb./ft.^{3}." These are, however, small points in a book which will be very useful for students taking a first course in Applied Mechanics.—A. W. BABISTER.

FLYING THE OMNIRANGE (4th Revised Edition). *C. A. Zweng and J. Dohm. Pan American Navigation Service, California, 1959. 153 pp. Illustrated. 4 dollars.*

There is no denying that V.O.R. is about the simplest, all-weatherest navaid a pilot could ask for. The authors make great play of this—in fact they rather overdo it. For though, near the end of the book, they briefly mention scalloping and accuracy-limitations, they do not dwell on the implications of these for the pilot. Should not the newcomer to V.O.R. be warned that if he intently followed the needle on every transmitter his path would sometimes be alarmingly "kurvenreich" (as the German roadsigns say)? Should he not be warned that the acceptable errors of receiver and transmitter can add up to six degrees, thus leaving him precious little airway-width for pilot error? And does not the cone-of-confusion present some problems to the pilot overflying a V.O.R. transmitter at high altitude?

The book is liberally flavoured with American air politics. It opens with a forthright, enthusiastic justification of the C.A.A. navaid programme, and it closes with a study of the battle which resulted in the V.O.R.T.A.C. compromise. Besides this and the main title-subject, there is information on how the omnirange works, on D.M.E. and the course-line computer, and on a number of V.O.R. receivers (one is surprised at the variety of ways in which a pilot can be presented with a magnetic bearing). It is written pleasantly, with a minimum of technical terms; for these a glossary is provided, and the reader would do well to note, at the start, exactly what the authors mean by "course."—B. E. E. MARSHALL.

HANDBOOK OF NOISE CONTROL. *C. M. Harris (Editor). McGraw-Hill, New York, 1957. 40 sections. Illustrated. 128s.*

In this age of jet noise, and structural damage to aircraft due to acoustic fatigue from jets, boundary layers and other sources, a large body of people in aircraft companies are now having to handle noise control problems. Since this is a relatively new field in the industry, it is not surprising that their knowledge of acoustics is strictly limited to that needed to understand their immediate problems, and their knowledge of the science of measurements and of physiological and industrial aspects is very limited. It is in this respect that this book provides an extremely valuable addition to the aeronautical engineer's bookshelf. Most aspects of "uncontrolled sound" and means of controlling it receive close attention in this comprehensive handbook and forty-six experts in the various fields give this book of over a thousand pages the authority and range to make it a real source of continual reference.

In the field of instrumentation, for example, extremely weighty chapters are contributed by Bruel and others, acoustic propagation is dealt with by Rudnick, aircraft noise by von Gierke, community reactions by Parrack and Stevens, legal aspects by Lucey, and other important aspects of the subject by such well-known authorities as Bolt, Ingard, Glorig, King, Crede and Leonard.

Similarly, in the field of industrial applications, the harassed engineer who now finds himself involved in the noise of helicopters or fan lift devices will gain confidence in handling such problems when he sees the present state of knowledge regarding such items as fan and compressor noise, gear noise and methods of vibration and noise isolation. Indeed, the chapters on fan noise and soundproofing indicate only too clearly the lack of scientific background involved in the present treatment of this subject.

A close study of two chapters will suffice to illustrate both the value and limitations of such a handbook of noise

control; incidentally, three such handbooks were announced in the one issue of the JOURNAL, when the present handbook was announced (*Additions to the Library*, January 1958).

Considering first the chapters on propeller and jet engines by von Gierke, the author has extracted in a masterly manner material drawn from over a hundred works, extending from Lighthill's theory to rocket test results and sonic bang theories. The treatment emphasises fundamental principles and this is likely to remain up-to-date for some time, in spite of the rapid rate of development in our knowledge of the mechanics of noise sources in moving streams.

Secondly, consider the chapter on the loudness of sounds by Morrison. This author explains the meaning of decibels, sones, mels, phons, and describes adequately the derivation of sones and phons from octave band and other spectra. There is no mention at all, however, of the latest units being used in the assessment of the subjective noise nuisances at the Idlewild and London Airports, namely, "noys" and "perceived noise levels." Since such units were not invented when the book was written, this is not a criticism of the author, but must be taken rather as a warning to the reader who may expect too much from any extensive handbook written to cover a rapidly developing subject.

Only a few of the aspects covered in this book have been mentioned, which has been written as much for the

The book covers a comprehensive range of components in its 500 pages, but obviously cannot mention every device invented for control system purposes. It is curious, however, that in the section on precision variable resistors no mention is made of the cam corrected type which is probably the most accurate of all. In the measurement of acceleration only linear acceleration is covered, whereas angular accelerometers, equally of importance, have no mention.

In all, there are thirteen chapters each concluded by a set of problems which according to the authors are "class-tested." The book is exclusively American as far as the references given and the manufacturers named. It is well written and sound. The aim throughout has been to discuss basic principles of operation, analysis of performance and development trends. It never descends to a mere catalogue and is admirably suited as a textbook to be read in parallel with studies in control theory.—J. C. WEST.

ELECTRICITY IN AIRCRAFT. *F. G. Spreadbury. Constable, London, 1958. 342 pp. Illustrated. 40s.*

This is yet another book from the pen of the virile writer F. G. Spreadbury, M.Inst.B.E., M.A.I.E.E., as one is reminded by the constant reference to his books in the bibliography at the end of each chapter.

Textbooks dealing with aircraft electrical engineering subjects are sorely needed, and this book is intended to

well as an insight into the C.A.A. Instrument Rating System.—B. E. E. MARSHALL.

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Additions to the Library

Aircraft and Missile Propulsion, Volume II. The Gas Turbine Power Plant, the Turboprop. Turbojet, Ramjet and Rocket Engines. M. J. Zucrow. John Wiley, New York (Chapman and Hall, London). 1958. 636 pp. Illustrated. 104s. *To be reviewed.*

Applied Mechanics. J. A. Cormack. Chatto and Windus, London, 1958. 342 pp. Illustrated. 25s. *Reviewed in this issue.*

Bonded Aircraft Structures. CIBA (A.R.L.) Ltd. 1959. 177 pp. Illustrated. 52s. 6d. *To be reviewed.*

Flying the Omnirange. C. A. Zweng and J. Dohm. Pan American Navigation Service, California. Weems System of Navigation, Maryland. 1957. 153 pp. Illustrated. 4 dollars. *Reviewed in this issue.*

Guide to the Literature of Mathematics and Physics Including Related Works on Engineering Science. Nathan Grier Parke. Dover Publications, New York. 1958. 436 pp. $2.75. *To be reviewed.*

Guided Missiles: Fundamentals. U.S. Department of the Air Force U.S.G.P.O. 575 pp. Illustrated. 31s. 6d. This is Air Force Manual 52-31, one of the publications that the authorities in America publish for the benefit of its armed forces to enable them to teach themselves the rudiments and more of technical subjects. The first four chapters deal with principles and the last seven with systems and components.

Instrument Flying. P. V. H. Weems and C. A. Zweng. Waverly Press, Baltimore. 1958. 298 pp. Illustrated.

Proposal for the Assembly of a Multi-Manned Satellite. S. B. Kramer and R. A. Byers. Lockheed Missile Systems Division. Illustrated. A paper prepared for the national meeting of the American Astronautical Society in December 1958. Part I deals with System Concepts and Part II Component Concepts. Appendices deal with such subjects as optical light filters, use of infra-red, space-station instruments. There are 16 tables of instrumentation.

Sampled Data Control Systems. E. I. Jury. John Wiley, New York. 1958. 453 pp. Illustrated. 128s. Describes the theory of sample-data control systems through a general approach to mixed digital-analogue linear systems and a thorough discussion of the *z*-transform method which can be applied to a wide variety of fields. Problems arising in feedback control systems are solved and discussed by means of application of digital computers. General applications of the *z*-transform method and the operational solution of linear difference equations are enumerated and clarified. Special emphasis is placed on the organisation, integration and extension of material governing industrial control methods. Contains problems and 112 references.

Scientific Uses of Earth Satellites. J. A. Van Allen. (Second Edition.) University of Michigan Press. 1958. 314 pp. Illustrated. 75s. The text has been extensively revised and brought up to date since the first edition.

This is a book which can be recommended [illegible] ing students of graduate level.—A. P. ROBERTS.

APPLIED MECHANICS. *J. A. Cormack. Chatto and Windus, London. 1959. 342 pp. Illustrated. 42s.*

This in an elementary textbook, written "for students who are reading Applied Mechanics at the S.3 stage for the Ordinary National Certificate and for those preparing for one of the professional examinations in this subject." A knowledge of elementary calculus (including simple integration) is assumed.

On the whole, the material is well set out and clearly presented, with a number of worked examples in the text. There are examples at the end of each chapter (many of these being taken from recent papers of the professional societies) and answers are given.

There are, however, one or two points which could be explained more clearly. The slug is mentioned on p. 4, but thereafter the author seems rather shy about referring to this useful animal. This is regrettable inasmuch as this is a book for practical engineers. The use of lb. mass and lb. wt. is very confusing for beginners. Simpson's rule is given without proof. Possibly the readers know the proof, but this is not worth risking. The section on scalar and vector products deserves at least one practical worked example.

In the treatment of the kinetic energy of combined translation and rotation it should be clearly stated that the kinetic energy of a rigid body is the sum of the kinetic energy due to the motion of the *centre of gravity* and that due to motion about this point. The example in this section is only correct under certain conditions.

There are misprints on p. 229 (Wg instead of W/g) and on p. 230 (a square root sign missing), while, in the chapter on hydrostatic pressure, w is called "the weight of liquid in lb./ft.^{3}." These are, however, small points in a book which will be very useful for students taking a first course in Applied Mechanics.—A. W. BABISTER.

HANDBOOK OF NOISE CONTROL. *C. M. Harris (Editor). McGraw-Hill, New York, 1957. 40 sections. Illustrated. 128s.*

In this age of jet noise, and structural damage to aircraft due to acoustic fatigue from jets, boundary layers and other sources, a large body of people in aircraft companies are now having to handle noise control problems. Since this is a relatively new field in the industry, it is not surprising that their knowledge of acoustics is strictly limited to that needed to understand their immediate problems, and their knowledge of the science of measurements and of physiological and industrial aspects is very limited. It is in this respect that this book provides an extremely valuable addition to the aeronautical engineer's bookshelf. Most aspects of "uncontrolled sound" and means of controlling it receive close attention in this comprehensive handbook and forty-six experts in the various fields give this book of over a thousand pages the authority and range to make it a real source of continual reference.

In the field of instrumentation, for example, extremely weighty chapters are contributed by Bruel and others, acoustic propagation is dealt with by Rudnick, aircraft noise by von Gierke, community reactions by Parrack and Stevens, legal aspects by Lucey, and other important aspects of the subject by such well-known authorities as Bolt, Ingard, Glorig, King, Crede and Leonard.

Similarly, in the field of industrial applications, the harassed engineer who now finds himself involved in the noise of helicopters or fan lift devices will gain confidence in handling such problems when he sees the present state of knowledge regarding such items as fan and compressor noise, gear noise and methods of vibration and noise isolation. Indeed, the chapters on fan noise and soundproofing indicate only too clearly the lack of scientific background involved in the present treatment of this subject.

A close study of two chapters will suffice to illustrate both the value and limitations of such a handbook of noise

control; incidentally, three such handbooks were announced in the one issue of the JOURNAL, when the present handbook was announced (*Additions to the Library*, January 1958).

Considering first the chapters on propeller and jet engines by von Gierke, the author has extracted in a masterly manner material drawn from over a hundred works, extending from Lighthill's theory to rocket test results and sonic bang theories. The treatment emphasises fundamental principles and this is likely to remain up-to-date for some time, in spite of the rapid rate of development in our knowledge of the mechanics of noise sources in moving streams.

Secondly, consider the chapter on the loudness of sounds by Morrison. This author explains the meaning of decibels, sones, mels, phons, and describes adequately the derivation of sones and phons from octave band and other spectra. There is no mention at all, however, of the latest units being used in the assessment of the subjective noise nuisances at the Idlewild and London Airports, namely, "noys" and "perceived noise levels." Since such units were not invented when the book was written, this is not a criticism of the author, but must be taken rather as a warning to the reader who may expect too much from any extensive handbook written to cover a rapidly developing subject.

Only a few of the aspects covered in this book have been mentioned, which has been written as much for the architect and the automobile engineer as for the aircraft industry. With these warnings, rather than criticisms, this book should be used quite widely in this country, in spite of its American type price.—E. J. RICHARDS.

CONTROL SYSTEM COMPONENTS. *J. E. Gibson and F. E. Tuteur. McGraw-Hill, London, 1958. 493 pp. Illustrated. 93s.*

There are now a large number of books concerned with the theory of automatic control. Most of them introduce only those particular components necessary to give practical examples of the theory. This book deals with the various items of equipment, component by component, that are found in the majority of control systems, whether hydraulic, pneumatic, electro-mechanical or electronic.

The components themselves fall easily into different classes depending on their function in the closed loop system. First are the measuring devices or transducers converting the quantities to be controlled into suitable signals. Then follow the error detectors or discriminators. The book has a whole chapter on these devices for use in the modulated carrier signal servomechanism.

Stabilising or shaping networks, although an important element in a complete system, can only be discussed with the overall system in mind and rightly are not considered to any great extent in a book on individual components. Signal and power amplifiers are dealt with in great detail, there being chapters on electronic d.c. amplifiers, electronic power amplifiers, electrical rotary amplifiers, pump controlled hydraulic systems, valve controlled hydraulic systems and pneumatic systems. The actuating member or servo-motor is also described using the same sub-divisions as for amplifiers.

Of great interest in the aeronautics field is the section on gyroscopes, and their applications in automatic flight and for inertial navigation. This is an extremely lucid section on a fairly difficult topic.

The book covers a comprehensive range of components in its 500 pages, but obviously cannot mention every device invented for control system purposes. It is curious, however, that in the section on precision variable resistors no mention is made of the cam corrected type which is probably the most accurate of all. In the measurement of acceleration only linear acceleration is covered, whereas angular accelerometers, equally of importance, have no mention.

In all, there are thirteen chapters each concluded by a set of problems which according to the authors are "class-tested." The book is exclusively American as far as the references given and the manufacturers named. It is well written and sound. The aim throughout has been to discuss basic principles of operation, analysis of performance and development trends. It never descends to a mere catalogue and is admirably suited as a textbook to be read in parallel with studies in control theory.—J. C. WEST.

ELECTRICITY IN AIRCRAFT. *F. G. Spreadbury. Constable, London, 1958. 342 pp. Illustrated. 40s.*

This is yet another book from the pen of the virile writer F. G. Spreadbury, M.Inst.B.E., M.A.I.E.E., as one is reminded by the constant reference to his books in the bibliography at the end of each chapter.

Textbooks dealing with aircraft electrical engineering subjects are sorely needed, and this book is intended to provide information on an intermediate level. One gets the impression that Mr. Spreadbury is out of touch with his subject, since in his book there are some inaccuracies and wide sweeping generalisations. For example, in Chapter 1 on page 4, he quotes the limiting sizes of d.c. generators without quoting their ratings or the speed range over which the generators are intended to operate. Incidentally, the sizes quoted are well below that of present day generators.

The book covers a very wide field and much of it will be of use to the aircraft electrical engineering student, but it is surprising that there are no photographs of generators, alternators, control gear or switchgear given, perhaps this omission will be rectified in later issues.

The chapter which covers generating systems is good, but incomplete; if only for history records, the Ambassador, Comet and Viscount systems might have been mentioned. All of the rectified generating systems mentioned are manufactured by one company yet no acknowledgments have been given. There is one error that must be pointed out—the Hermes system is a dual-voltage system, not triple, and this is confirmed by the circuit diagrams shown on Fig. 2.22, page 100.

Mr. Spreadbury's remarks on rotary inverters and converters, and batteries are good and interesting. More could have been written on zinc/silver oxide batteries, and the charging of batteries in very cold conditions. Switchgear and cables are dealt with in an interesting way with an occasional neologism to set the reader thinking.

The chapter on testing and test equipment is good. This is not surprising, since the author has spent many years designing and producing test gear, for the company with which he is associated.

Mr. Spreadbury is aiming high when he considers this book to be intended for use by intermediate level students. Mathematically it *is* of the intermediate level, but for electrical knowledge of the aircraft industry and the study of environmental conditions it is of a lower level.—G. G. WAKEFIELD.

Additions to the Library

Aircraft and Missile Propulsion, Volume II. The Gas Turbine Power Plant, the Turboprop, Turbojet, Ramjet and Rocket Engines. M. J. Zucrow. John Wiley, New York (Chapman and Hall, London). 1958. 636 pp. Illustrated. 104s. *To be reviewed.*

Applied Mechanics. J. A. Cormack. Chatto and Windus, London, 1958. 342 pp. Illustrated. 25s. *Reviewed in this issue.*

Bonded Aircraft Structures. CIBA (A.R.L.) Ltd. 1959. 177 pp. Illustrated. 52s. 6d. *To be reviewed.*

Flying the Omnirange. C. A. Zweng and J. Dohm. Pan American Navigation Service, California, Weems System of Navigation, Maryland. 1957. 153 pp. Illustrated. 4 dollars. *Reviewed in this issue.*

Guide to the Literature of Mathematics and Physics Including Related Works on Engineering Science. Nathan Grier Parke. Dover Publications, New York. 1958. 436 pp. $2.75. *To be reviewed.*

Guided Missiles: Fundamentals. U.S. Department of the Air Force U.S.G.P.O. 575 pp. Illustrated. 31s. 6d. This is Air Force Manual 52-31, one of the publications that the authorities in America publish for the benefit of its armed forces to enable them to teach themselves the rudiments and more of technical subjects. The first four chapters deal with principles and the last seven with systems and components.

Instrument Flying. P. V. H. Weems and C. A. Zweng. Waverly Press, Baltimore. 1958. 298 pp. Illustrated. $6. *Reviewed in this issue.*

Lager- und Schmiertechnik. (Bearing and Lubrication Techniques.) R. Kamps. V.D.I., Dusseldorf. 1957. 364 pp. Illustrated. (In German.) A survey of modern lubricating and bearing techniques, covering the whole field of ball- and roller-bearings; includes also a new method of calculating the life and endurance of bearings, among other unpublished experimental results. There is an extensive bibliography with each chapter.

Potential Theory of Unsteady Supersonic Flow, The. J. W. Miles. Cambridge University Press, London. 1959. 220 pp. Illustrated. 45s. *To be reviewed.*

Prediction of Ballistic Missile Trajectories from Radar Observations, The. Irwin I. Shapiro. McGraw-Hill, New York. 1958. 208 pp. Illustrated. Intended to develop methods, based on the statistical theory of parameter estimation, that can be used to determine ballistic missile trajectories from observations of the missile by monostatic radar at one or more sites. The methods can be slightly modified, to estimate the osculating parameters of satellite orbits but, for long-time intervals after observation, more serious modifications are needed, to account for atmospheric drag and so on.

Proposal for the Assembly of a Multi-Manned Satellite. S. B. Kramer and R. A. Byers. Lockheed Missile Systems Division. Illustrated. A paper prepared for the national meeting of the American Astronautical Society in December 1958. Part I deals with System Concepts and Part II Component Concepts. Appendices deal with such subjects as optical light filters, use of infra-red, space-station instruments. There are 16 tables of instrumentation.

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Scientific Uses of Earth Satellites. J. A. Van Allen. (Second Edition.) University of Michigan Press. 1958. 314 pp. Illustrated. 75s. The text has been extensively revised and brought up to date since the first edition, reviewed in the JOURNAL of November 1957 (p. 783). The 33 papers were originally presented at the tenth anniversary meeting of the Upper Atmosphere Rocket Research Panel, at the University of Michigan in January 1956. The subject matter is the use of the satellite for physical research, not the satellite itself, and its aeronautical application is rather indirect.

Synthesis of Linear Communication Networks, Volume I. W. Cauer. McGraw-Hill, London. 1958. 866 pp. Illustrated. 151s. *To be reviewed.*

Theory of Machines. B. B. Low. Longmans Green, London, 1958. 522 pp. Illustrated. 25s. First published under the title *Engineering Mechanics* in 1942. The second edition was reviewed in the JOURNAL of July 1954 (p. 513) where it was "especially to be commended for the very clear and readable style" and "covers very satisfactorily the scope of the examination syllabuses for the Engineering Institutions and Higher National Certificate." In this new edition two chapters have been added to increase the ground covered on Vibrations and an article is now included on Hooke's Joint.

Reports

AERODYNAMICS

COMPRESSIBLE FLOW—*see also* LOADS
WINGS AND AEROFOILS
THERMODYNAMICS

Effects of some changes in body length and nose shape on the aerodynamic characteristics of wing-body combinations at supersonic speeds. S. Tomlin and A. Stanbrook. C.P. 413. 1958. Three bodies have been tested alone, and in combination with each of two wings, at Mach numbers of 1·42 and 1·61, to find the effect of body length and nose shape on the aerodynamic characteristics of the wing-body combinations.—(1.2.3).

The effects of combined electric and magnetic fields on hypersonic Couette flow. Z. O. Bleviss. Douglas Rep. SM-23314. Oct. 1958.—(1.2.4.1).

CONTROL SURFACES—*see also* WINGS AND AEROFOILS

Wind tunnel tests on a 6% two-dimensional aerofoil with 25% chord flap. P. E. Turner. ARL Note A. 164. *Dec.* 1958.
Results are presented in the form of pressure distributions and the associated lift and moment coefficients together with wake profiles and the resulting drag coefficients. Hinge moment and flap normal force coefficients are included for the deflected flap. —(1.3.4×1.10.2.1).

INTERNAL FLOW—*see also* WINGS AND AEROFOILS

Aspect-ratio effects on compressor cascade blade flutter. D. A. Kilpatrick and R. A. Burrows. R & M 3103. 1958.—(1.5.4.2×2).

Use of short flat vanes for producing efficient wide-angle two-dimensional subsonic diffusers. D. L. Cochran and S. J. Kline. N.A.C.A. TN. 4309. *Sept.* 1958.
Using optimum designs of vane installations, high pressure recoveries and steady flows were obtained for diffuser-wall divergence angles up to 42°. Criteria for optimum configurations were developed.—(1.5.1).

LOADS

Calculated aerodynamic forces on a sweptback untapered wing oscillating in incompressible flow. D. L. Woodcock. C.P. 411. 1958.—(1.6.3×1.10.1.2×2).

Theoretical studies of unsteady transonic flow. Part II. The oscillating semi-infinite rectangular wing. M. T. Landahl. FFA Rep. 78. 1958.
By use of Fourier transforms the aerodynamic forces on an oscillating semi-infinite rectangular wing in transonic flow are calculated. The results may be used to obtain approximate air forces on a finite rectangular wing for not too low values of $A\sqrt{k}$, where A is aspect ratio and k reduced frequency.—(1.6.3×1.2.2.1).

Theoretical studies of unsteady transonic flow. Part III. The oscillating low aspect ratio rectangular wing. M. T. Landahl. FFA Rep. 79. 1958.
By expanding the velocity potential in an asymptotic series, the aerodynamic forces on an oscillating low aspect ratio rectangular wing are calculated. Formulae for the calculation of generalised forces for any smooth, flexible or rigid mode of oscillation with spanwise symmetry are given.—(1.6.3×1.2.2.1).

STABILITY AND CONTROL—*see also* WINGS AND AEROFOILS

Ground simulator studies of the effects of valve friction, stick friction, flexibility, and backlash on power control system quality. B. P. Brown. N.A.C.A. Rep. 1348. 1958.
Boundaries are determined for good, tolerable, and unsatisfactory ranges of valve and stick friction for a rigid control system and a system with flexibility between the source of stick friction and the valve. The effect of various friction ratios with flexibility between the pilot and the source of stick friction is presented. The effect of backlash with various friction ratios is also presented.—(1.8.2.1).

WINGS AND AEROFOILS—*see also* CONTROL SURFACES
LOADS

Low-speed wind-tunnel tests of the effects of various leading-edge modifications on the sectional characteristics of a thin wing. S. F. J. Butler. C.P. 410. 1958.
The effects of various leading-edge modifications on the low-speed characteristics of a 6 per cent RAE101 aerofoil are discussed, with particular attention to the effects on the upper surface flow separations. The effects of attaching an isolated strake and a row of strakes to the leading-edge were investigated. Tests were also made on a sharp-nosed version, both with and without deflected nose flap. A comparison is included between the measured pressure distributions, and distributions calculated assuming no flow separations.—(1.10.2.1).

Velocity distribution on thin tapered arrowhead and delta wings with spanwise constant thickness ratio at zero incidence. S. Neumark et al. R. & M. 3008. 1958.
A theoretical investigation was made of subsonic flow past thin tapered swept-back wings at zero incidence, by the first-order method. The basic theory is followed by the results of computation done on the A.C.E. of the National Physical Laboratory, for several groups of plan forms, partly of arrowhead and partly delta type, with varying sweepback, aspect ratio and taper, the profile being biconvex parabolic and thickness ratio constant spanwise. The results are illustrated by graphs of isobar patterns on 36 wings.—(1.10.1.2×1.2.1.1).

Calculated derivatives for rectangular wings oscillating in compressible subsonic flow. D. H. Lehrian. R. & M. 3068. 1958.
Stability and flutter derivatives are obtained for rectangular wings describing plunging and pitching oscillations in subsonic flow. These are evaluated by applying the simple approximate "equivalent" wing theory with the vortex-lattice method of downwash calculation. The derivatives for the wing of aspect ratio 4 at Mach number 0·866 are compared with values calculated by exact theory.—(1.10.1.2×1.5.2.2×2).

Observations of the flow past a two dimensional 4 per cent thick biconvex aerofoil at high subsonic speeds. B. D. Henshall and R. F. Cash. R. & M. 3092. 1958.
Flow photographs and detailed pressure distributions for a 4 per cent thick circular-arc biconvex aerofoil at high subsonic speeds and high incidences have been analysed and the divergence boundary (defining the onset of separation effects) for the aerofoil determined. Emphasis was placed on the transition from leading-edge to shock-induced separation as the free-stream Mach number was raised at a fixed incidence.—(1.10.2.1).

Observations of the flow patterns of a two dimensional 4 per cent thick biconvex aerofoil at $M_0 = 1{\cdot}40$ *and* $1{\cdot}63$. *B. D. Henshall and R. F. Cash. R. & M.* 3093. 1958.—(1.10.2.1).

A summary and analysis of the low-speed longitudinal characteristics of swept wings at high Reynolds number. G. C. Furlong and J. G. McHugh. N.A.C.A. Report 1339. 1958.
An analysis of the longitudinal characteristics of swept wings which is based on available large scale low speed data and supplemented with low scale data when feasible is presented. The emphasis has been placed on the differentiation of the characteristics by a differentiation between the basic flow phenomenon involved.—(1.10.2.2×1.8.2.1×1.3.4).

Ordinates and theoretical pressure-distribution data for N.A.C.A. 6- and 6A-series airfoil sections with thicknesses from 2 to 21 and from 2 to 15 per cent chord, respectively. E. W. Patterson and A. L. Braslow. N.A.C.A. T.N. 4322. *September* 1958.
Information is presented with which ordinates can be easily obtained for any thickness from 2 to 21 per cent chord for N.A.C.A. 63-, 64-, and 65-series aerofoil sections and from 2 to 15 per cent chord for N.A.C.A. 63A-, 64A, and 65A-series aerofoil sections. Data required for estimation of the theoretical pressure distributions of these aerofoils are given.—(1.10.0.1).

Effects of propeller position and overlap on the slipstream deflection characteristics of a wing-propeller configuration equipped with a sliding and Fowler flap. W. C. Hayes et al. N.A.C.A. T.N. 4404. *September* 1958.—(1.10.2.2×1.3.4×29).

Effects of ground proximity on the thrust of a simple downward-directed jet beneath a flat surface. K. P. Spreemann and I. R. Sherman. N.A.C.A. T.N. 4407. *September* 1958.
An investigation to determine the effects of some of the basic parameters on the thrust of a simple downward-directed jet beneath a lifting surface has been conducted in a static thrust facility at the Langley Aeronautical Laboratory. Some of the principal variables investigated were size and shape of the lifting surface and distance of lifting surface and nozzle exit above the ground. Devices to minimise the negative induced lift in close proximity to the ground were also investigated.—(1.10.2.2×27.1).

HELICOPTER AERODYNAMICS

A method of calculating the effect of one helicopter rotor upon another. I. C. Cheeseman. C.P. 406. 1958.
A model of the induced flow around a lifting rotor is derived by considering a lifting line approximation to translational lift and a stream tube model for propeller lift. This theory is applied to a tandem rotor configuration in rectilinear flight.—(1.11.3).

Wind tunnel tests of a full-scale helicopter rotor with symmetrical and with cambered blade sections at advanced ratios from 0·3 to 0·4. J. L. McCloud and G. B. McCullough. N.A.C.A. T.N. 4367. *September* 1958.—(1.11.3).

Some static longitudinal stability characteristics of an overlapped-type tandem-rotor helicopter at low airspeeds. R. J. Tapscott. N.A.C.A. T.N. 4393. *September* 1958.—(1.11.2).

Flight measurements of the vibration experienced by a tandem helicopter in transition, vortex-ring state, landing approach, and vawed flight. J. E. Yeates. N.A.C.A. T.N. 4409. *Sept.* 1958.
Some results of vibration measurements during transition near the ground are presented, and the change in magnitude of the vibration with increasing rotor speed is shown. The pulsative nature of the vibration during vortex-ring state and the reduction in vibration with increasing yaw angle are discussed.—(1.11.2).

AEROELASTICITY

See also AERODYNAMICS—INTERNAL FLOW
LOADS
WINGS AND AEROFOILS

Procedure for calculating flutter at high supersonic speed including camber deflections, and comparison with experimental results. H. G. Morgan et al. N.A.C.A. T.N. 4335. *Sept.* 1958.
A method suitable for digital computation is described for calculating the flutter speed at high supersonic Mach numbers of wings with camber in their deflection modes. The wing may have a control surface and carry an external store. A normal-mode analysis is used, the camber deflection in the vibration modes being approximated by polynomials. Aerodynamic forces are obtained by piston theory with the aerofoil shape

and thickness terms included and by a quasi-steady method based on two dimensional steady flow.—(2).

Use of the kernel function in a three dimensional flutter analysis with application to a flutter tested delta wing model. D. S. Woolston and J. L. Sewall. N.A.C.A. T.N. 4395. *Sept.* 1958.
A Rayleigh-Ritz, or modal, type of flutter analysis, based on the use of the kernel function in the determination of the aerodynamic forces, has been developed and applied to a delta semi-span wing with a leading-edge sweep angle of 45° which fluttered as a cantilever at a Mach number of 0·85.—(2).

AIRCRAFT OPERATION

Lightning hazards to aircraft fuel tanks. J. D. Robb et al. N.A.C.A. T.N. 4326. *September* 1958.
The hazards of lightning strokes to aircraft fuel tanks were investigated in artificial lightning generation facilities constructed to duplicate closely the natural lightning discharge to aircraft.—(5.3×32.2.1).

An investigation of some phenomena relating to aural detection of airplanes. H. H. Hubbard and D. J. Maglieri. N.A.C.A. T.N. 4337. *September* 1958.
Conventional noise level measurements consisting of frequency analyses were made for static ground tests of a single-engine aeroplane. Also, listening data with the aid of ground observers were obtained in flight during cruise, take-offs, landings, and and power-off glides.—(5.6).

A tumbling aerofoil radio distress beacon system for locating crashed aircraft. H. T. Stevinson and D. Makow. N.R.C. Rep. MR-22. *July* 1958.—(5.3).

Untersuchung über die Möglichkeiten des Verkehrseinsatzes von Hubschraubern im Nahverkehr und zwischen Verkehrsflughäfen für Flächenflugzeuge. Teil I. Der Hubschrauber als Schnellverkehrsmittel. Teil II. Die Einsatzmöglichkeiten innerhalb der Bundesrepublik Deutschland. V. Porger. DSH Bericht 23. *September* 1956. *(In German.)*
The helicopter for rapid transportation and the practicability of its utilisation in Germany are dealt with.—(5).

EXTRA-ATMOSPHERIC TECHNOLOGY

Optical properties of Saturn's rings; I. Transmission. A. F. Cook and F. A. Franklin. Smithsonian Cont. to Astrophysics. Vol. 2, *No.* 13. 1958.
All existing observational data relating to the transmission properties of Saturn's rings are discussed. From such data the optical thickness of the Crape ring is determined as a function of its distance from the planet. Limiting values for ring *B* and a new value for the inner radius of ring *B* are established. The shape of the pressure curve of a gas cloud evidently associated with ring *C* can be computed from its optical thickness.—(8.1).

The regression of the node of the quadrantids. G. S. Hawkins and R. B. Southworth. Smithsonian Conts. Astrophysics. Vol. 3, *No.* 1. 1958.
Observations of the longitude of the descending node of the Quadrantid meteor stream from 1838 to 1954 are assembled and discussed. It is concluded that the majority of the older observations were made in years of unusually high activity. The descending node of the observed stream has regressed 0·6° per century.—(8.1).

Catalogs of meteor radiants. G. S. Hawkins. Smithsonian Conts. Astrophysics. Vol. 3, *No.* 2. 1958.
Denning's historic catalogue of 3,035 radiant points has been examined in the light of modern knowledge.—(8.1).

FLIGHT TESTING

See also PROPELLERS

A flight technique for the measurement of thrust boundaries and of drag due to lift. H. D. Rylands. C.P. 405. 1958.
A new technique is proposed for supersonic aircraft which will also have many advantages over existing methods for subsonic types. Some data on drag due to lift can also be obtained without the need for thrust measurement. Preliminary flight trials on a subsonic aircraft proved very satisfactory. No major difficulties are anticipated when the technique is applied to supersonic aircraft.—(13.1).

FUELS AND LUBRICANTS

See also—THERMODYNAMICS

Effect of fuel variables on carbon formation in turbo-jet engine combustors. E. R. Jonash et al. N.A.C.A. Report 1352. 1958.
Three empirical fuel factors satisfactorily correlated combustor deposit and exhaust-gas smoke data obtained at one operating condition in a single tubular turbo-jet combustor and in several full-scale engines. A number of organo-metallic compounds, commercial additives, and oxygen-bearing compounds markedly reduced deposits in the single combustor.—(14×27.1).

HYDRODYNAMICS

Water-impact theory for aircraft equipped with nontrimming hydro-skis mounted on shock struts. E. Schnitzer. N.A.C.A. T.N. 4256. *September* 1958.
Theoretical equations are derived for the motions of aircraft equipped with shock-mounted hydro-skis impacting on a water surface. A rough approximation to the hydrodynamic force term is included in a non-dimensional form which permits design trend study solutions for a wide range of practical impacts. A second or better approximation to the hydrodynamic force is included in a dimensional form.—(17.2).

Hydrodynamic impact loads on 30° *and* 60° *V-step plan form models with and without dead rise. P. M. Edge and J. P. Mason. N.A.C.A. T.N.* 4401. *September* 1958.
Tests were made with models having round keels, straight intermediate sections, and chine flare. These tests were in smooth water at fixed trims over a range of landing conditions at a beam loading coefficient of 3·6.—(17.2).

MATERIALS

The behaviour of polymethyl methacrylate under repeated load. F. G. Lewis. A.R.L. Note MET 10. *July* 1958.
A review of the published information on the properties of polymethyl methacrylate shows that the material is subject to failure under repeated load at a stress lower than the static strength, in a manner analogous to a metal. The endurance strength of unplasticised perspex is between 2,200 and 2,700 lb./in.^{2} at 10^7 cycles of stress. This endurance is sensitive to changes of temperature and of the frequency of loading. Fracture patterns in polymethyl methacrylate appear, on a macroscopic scale, to be connected primarily with the type of stress system producing the failure and to a lesser extent with material factors such as molecular size, condition and treatment. These factors control the finer detail of the fracture pattern. A closer study of fracture patterns might allow the development of a method for assessing the nature of service failures. Deficiencies in the knowledge of the endurance characteristics of polymethyl methacrylate are discussed both from a practical and from a theoretical view point.—(21.3.3).

MATHEMATICS

The R.A.E. Hollerith punched-card installation (1945-1952). *R. A. Fairthorne et al. R. & M.* 3084. 1958.
The scope and working of the punched-card installation in Mathematics Services Department, R.A.E., from 1945 to 1952, is sketched. Types of work for which the equipment is best suited are indicated and some representative computing problems handled by the equipment are discussed.—(22).

Studies on the acceleration of a body from rest. Part II. The dependence of the distance traveled and the velocity attained on the shape and initial value of the acceleration curve for certain families of velocity dependent accelerations. J. L. Hess. Douglas Report E.S. 26708. *November* 1958.—(22.3).

Optimum equi-distant strip formulae in numerical quadrature J. Guest. A.R.L. Note G.W. 7. *August* 1958.
Seven formulae for numerical quadrature have been derived by replacing $f(a+nh)$ by its Taylor equivalent as a power series in h and various derivatives of $f(a)$, with a view to keeping the error to a minimum. The first three formulae are well known. Also a ten strip formula has been derived with relaxed conditions, *i.e.* some accuracy was sacrificed in favour of simpler coefficients.—(22).

On the representation of an arbitrary function by an integral involving Macdonald functions of complex order. N. N. Lebedev. A.R.L. Trans. 16. *August* 1958.—(22.1).

Actes des colloques de calcul numerique. Caen 1955—*Dijon* 1956. *P. Vernotte. Pubs. Sc. et Tech. N.T.*77. 1958.—(22.1).

MECHANICAL ENGINEERING

Théorie générale: conception et calcul des servo-mécanismes. R. Moreau. O.N.E.R.A. Pub. 93. 1958. (*In French.*)—(23.3).

On the use of spectral densities in the study of servo circuits defined by linear differential equations with time-variable coefficients and stochastic right member. M. Sundström and K. Flodin. KTH Aero T.N. 44. 1957.
A method is presented for the study of linear differential equations with time-variable coefficients and stochastic right member. The inputs of the servo systems are assumed to be characterised by spectral densities with two frequencies. The power spectral densities of the outputs are derived.—(23.3).

Relations between spectral densities of inputs and outputs in linear servo systems with time-variable coefficients. M. Sundström. KTH Aero T.N. 45. 1957.
From the relations between the Fourier transforms of inputs and outputs in linear servo circuits with time dependent coefficients, equations are derived between the corresponding spectral densities. Relations between the correlation functions are also considered. By means of the latter functions, the spectral densities can be calculated. The problem of computing the standard deviations of the outputs is dealt with.—(23.3).

Short account of the theories for the study of servo systems defined by linear differential equations with constant coefficients and influenced by stochastic disturbances. M. Sundström and K. Flodin. KTH Aero T.N. 46. 1957.
Some basic concepts as stochastic processes, correlation functions and spectral representations are explained. The differential equations of the servo system are transformed into linear, algebriac equations between modified Fourier transforms of inputs and outputs. Hence the spectral densities of the outputs can be written as linear expressions of the spectral densities of the inputs. The conditions for the outputs to be stationary are investigated.—(23.3).

POWER PLANTS

See also AERODYNAMICS—WINGS AND AEROFOILS
FUELS AND LUBRICANTS
STRUCTURES—TESTING

Effect of chord size on weight and cooling characteristics of air-cooled turbine blades. J. B. Esgar et al. N.A.C.A. Report 1354 (*supersedes T.N.* 3923). 1958.
Analysis shows that turbine blade weight is affected to a much smaller degree by the size of the blade chord for air-cooled blades than for solid uncooled blades. The heat transfer analysis shows that considerable savings in coolant flow are possible by using a smaller number of large chord blades rather than a larger number of small chord blades.—(27.1×34.3).

Theoretical and experimental analysis of the reduction of rotor blade vibration in turbomachinery through the use of modified stator vane spacing. R. H. Kemp et al. N.A.C.A. T.N. 4373. *September* 1958.
Theoretical analysis indicates that the vibration excitation originating in the stator vane assemblies of turbomachinery can be reduced 68 per cent by altering the circumferential positions of the individual vanes in a prescribed manner by amounts less than ±10 per cent of the normal spacing. Experimental verification of the analysis was obtained when two different stator vane assemblies were used.—(27.1).

Torque-speed characteristics for high specific work turbines. W. L. Stewart. N.A.C.A. T.N. 4379. *September* 1958.
These characteristics are presented in a general form using the ideal specific work output corresponding to the turbine static-to total-pressure ratio as the normalising parameter. Single-, two- and three-stage turbines are considered analytically with experimental verification. The analytical results are used to provide a basis for determining the effects of design criticalness and turbine staging on starting torque margin.—(27.1).

An analysis of ram-jet engines using supersonic combustion. R. J. Weber and J. S. MacKay. N.A.C.A. T.N. 4386. *September* 1958.
Based on the premise that supersonic burning is possible, the performance of ram-jet cycles utilising supersonic combustor velocities is calculated over a range of flight Mach numbers from 4 to 7. The effects of parameters such as inlet design, combustor area, divergence, wall friction, and nozzle performance are considered. Estimates of engine weight and cooling loads are included.—(27.4×34.1.1).

PROPELLERS

See also—AERODYNAMICS—WINGS AND AEROFOILS

Flight measurements of the vibratory stresses on a propeller designed for an advance ratio of 4·0 *and a Mach number of* 0·82. *T. C. O'Bryan. N.A.C.A. T.N.* 4410. *Sept.* 1958.
The vibratory stresses on the propeller were low in relation to the strength of the material.—(29.8×29.7×13.2×33.1.2).

SCIENCE—GENERAL

See AIRCRAFT OPERATION

STRUCTURES

LOADS—*see* PROPELLERS

THEORY AND ANALYSIS

*Theoretical analysis of the heating of a composite slab, with applications to the kinetic heating of an aircraft wing. E.C. Capey and K. I. McKenzie. C.P.*412. 1958.
The transient temperature distribution is derived for a composite slab, heated by raising the air temperature on one side at a constant rate to a maximum. Numerical results are evaluated on a digital computer from the theoretical solution, which is obtained in series form. Results are obtained for the temperature difference across the skin in an aircraft wing covered by insulative material.—(33.2.3.1.9×34.3).

A variational theorem for creep with applications to plates and columns. J. L. Sanders et al. N.A.C.A. Rep. 1342. 1958.
A variational theorem is presented for a body undergoing creep. Solutions to problems of the creep behaviour of plates, columns, beams, and shells can be obtained by means of the direct methods of the calculus of variations in conjunction with the stated theorem. The application of the theorem is illustrated for plates and columns by the solution of two sample problems.—(33.2.4.0.9).

TESTING

Spannungsoptische Untersuchungen von Turbinenscheiben mit angefrästen und eingesetzten Schaufeln. K. Leist and J. Weber. Forsch. W und VM Nordrhein-Westfalen. No. 548. 1958. (*In German.*)—(33.3.2×27.1).

THERMODYNAMICS

See also POWER PLANTS
STRUCTURES—THEORY AND ANALYSIS

Graphs of reduced variables for computing histories of vaporizing fuel drops, and drop histories under pressure. G. L. Borman et al. N.A.C.A. T.N. 4338. *September* 1958.
The objectives of this investigation were: (1) To obtain experimental data for single droplets vaporising at pressures greater than 1 atmosphere and to compare these data with theoretical predictions; (2) to evolve a simplified calculation technique to obtain droplet histories easily.—(34.2×14).

Effect of pressure and duct geometry on bluff-body flame stabilization. A. E. Potter and E. L. Wong. N.A.C.A. T.N. 4381. *September* 1958.
Blow-off velocities and recirculation-zone lengths of propane-air flames stabilised by cylindrical flame holders were measured as a function of pressure, fuel-air ratio, cylinder diameter and tunnel geometry.—(34.1.1).

Molecular and compressibility effects on forced convection of heat from cylinders. D. C. Collis and M. J. Williams. A.R.L. Rep. A 110. *July* 1958.
Theoretical and experimental contributions to this subject are reviewed. Interest has been restricted to Reynolds numbers less than 1,000. Topics discussed in some detail are Reynolds number dependence, Mach number effects, Knudsen number correlations and the non-linear effect of temperature loading.—(34.3.2×1.2).

APPOINTMENTS

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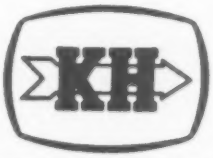

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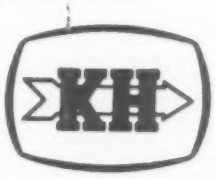

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